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MOISTURE AVAILABILITY AND AGRICULTURAL POTENTIALITIES OF MALI AND NIGER

by
E. Ofori-Sarpong*

ABSTRACT

One of the greatest factors limiting agricultural development in arid and semi-arid regions of Africa is lack of moisture. A country with adequate moisture has a great potential for agricultural development. It is againts this background that this paper focuses on the application of Hargreaves monthly moisture availability index classification to Mali and Niger in West Africa. The two countries are classified into moisture regions on the basis of the index and their relative agricultural potentials are assessed.

INTRODUCTION

The republics of Mali and Niger are former francophone West African countries are basically agricultural. They are landlocked and due to recurrent drought afflictions their economies have not been able to pay their way. The greatest obstacle to agricultural development in these countries is lack of water. An attempt has therefore been made to employ the moisture regions and assess their suitability for rainfed agriculture.

BACKGROUND

Mali has a total land area of 1,240,710 square kilometer and lies between latitudes 11^0N and 25^0N. The two countries depend upon their Southern neighbours for access to the sea due to their landlocked location. Mali has a population density of about 5.1 persons per square kilometer (1976) while Niger has 3.3 persons per square kilometer (1971). Over 80 percent of the inhabitants of both countries are heavily concentrated in the south and southwest along the valley of river Niger. In Mali the river Niger flows for 1500 km while in Niger Republic it flows for 300 km in the Southwestern part.

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The climate of these two countries is tropical continental and rainfall is associated with the inter-tropical discontinuity (ITD) whose northward movement in summer brings rainfall, while its southward movement brings dry conditions in the harmattan season. As a result from the south and southwest to the north. Consequently the lenght of the growing season reduces northward. Both countries have two seasons, the short rainy season which lasts for 4 months (June to September) and long dry season which lasts from October until June. The maximum rainfall is in August in both countries. One characteristic feature of the climate in both countries is the unreliability and uncertainty of the rains (Nicholson, 1980, 1983; Ofori-Sarpong, 1987). Variability of rainfall in time and space is high. In Mali, the annual rainfall varies from 1300 mm in the south to less than 20 mm in the north (Fig.1). For instance, Sikasso has an annual mean rainfall of about 1300 mm in the south while Tessalit (20^0 12^0N) receive about 87 mm. There are no rainfall stations beyond the latitude of Tessalit but it is expected that the areas beyond have less than 10 mm a year due to their desert location. In Niger Republic mean annual rainfall decreases from about 800 mm in the southwest to less than 19 mm in the northwest in 834 mm and falls off to about 19 mm at Bilma (18^0 41^0N)(Fig.2). There are no stations beyond 20^0N. However it is very probable that areas beyond 20^0N receive no rainfall due to their desert location. Mali embraces all the three Savannah bioclimates - Guinea, Sudan and Sahel, while Niger republic has two - Sudan and Sahel (Figs. 3 & 4). In both countries the desert is located beyond 17^0N.

METHODOLOGY

The monthly moisture availability index used to classify Mali and Niger into moisture regions was proposed by Hargreaves (1972) and is in Table 1. The moisture availability index (MAI) is a ratio of dependable precipitation to potential evapotranspiration (PE). Hargreaves indicated that 75 percent probability of rainfall occurence is a much more reliable indication of moisture available for crop production than mean precipitation. The dependable precipitation that has a specified probability of occurence (at least 3 or 4 years) based on the longterm records (Ofori-Sarpong, 1987). The rainfall records for the stations used in the analysis exceed 25 years. The PE values were obtained by using the Reddy and Virmani (1980) method based on Penman's approach. The monthly moisture availability index values were computed for 17 locations in Mali and 15 locations in Niger. Hargreaves (1974) employed a classification based on his monthly moisture availability index to examine crop zonation in northeast Brazil (Table 2). The same classification is used in this study to identify the suitability of rainfed agriculture in the two countries. The dependable precipitation and the potential evapotranspiration values for the selected stations are shown in Table 3 and 4.

RESULTS

Table 5 illustrated the monthly moisture availability indices calculated for 17 locations in Mali. The availability of moisture is very deficient between October and June in most parts of the country. Moisture availability becomes adequate in the rainy season in some parts while in the wetter parts it becomes exessive. Locations

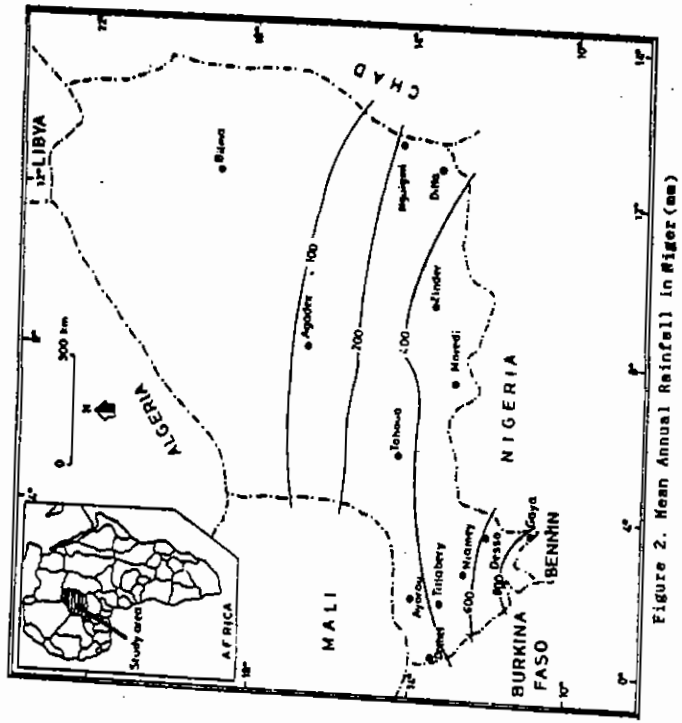

Figure 2. Mean Annual Rainfall in Niger (mm)

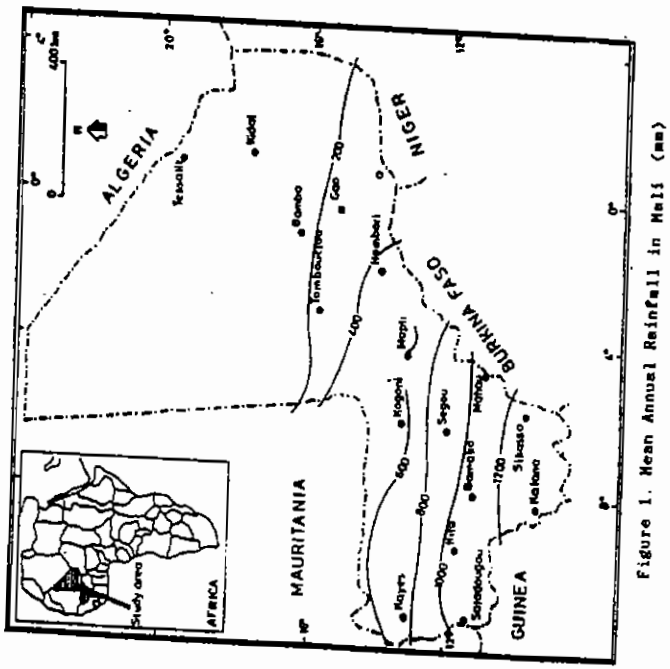

Figure 1. Mean Annual Rainfall in Mali (mm)

TABLE 1. HARGREAVES MONTHLY MOISTURE AVAILABILITY INDEX CLASSIFI CATION

Moisture Availability Index (MAI)	Classification
0.00 - 0.33	Very deficient
0.34 - 0.67	Moderately deficient
0.68 - 1.00	Somewhat deficient
1.01 - 1.33	Adequate
> 1.34	Excessive

Source : Hargreaves (1972).

TABLE 2. HARGREAVES CLIMATIC CLASSIFICATION AND AGRICULTURAL SUITABILITY

Criterion	Classification	Agricultural Suitability
All months with MAI of 0.33 or below	Very Arid	Not suited for rainfed agriculture
One or two months with MAI of 0.34 or above	Arid	Limited suitability for rainfed agriculture
Three or four consecutive months with MAI of 0.34 or	Semi-Arid 3 - 4 months growing above	Production possible for crops requiring season
Five or more consecutive months with MAI of 0.34 or above	Wet-dry	Production possible for crops requiring a good level of moisture adequacy during 5 or more months

Source: Hargreaves (1974)

TABLE 3. DEPENDABLE PRECIPITATION AND POTENTIAL EVAPOTRANSPIRATION (PE in Brackets mm) FOR SELECTED STATIONS IN MALI

	J	F	M	A	M	J	J	A	S	O	N	D
Tessalit	(126) 0	(165) 0	(205) 0	(230) 0	(240) 0	(205) 2	(279) 6	(156) 19	(172) 5	(177) 0	(147) 0	(136) 0
Kidal0	(132) 0	(165) 0	(210) 0	(224) 1	(240) 3	(214) 18	(182) 33	(161) 9	(174) 0	(181) 0	(147) 0	(136)
Bamba	(137) 0	(165) 0	(213) 0	(227) 0	(240) 1	(220) 6	(185) 25	(169) 53	(174) 9	(177) 1	(146) 0	(137) 0
Toumbouctou	(138) 0	(165) 0	(212) 0	(230) 0	(232) 1	(209) 6	(170) 34	(157) 52	(161) 18	(165) 1	(43) 0	(133) 0
Gao	(141) 0	(165) 0	(213) 0	(221) 0	(246) 1	(227) 10	(200) 46	(171) 76	(182) 17	(181) 2	(147) 0	(141) 0
Hombori	(143) 0	(163) 0	(211) 0	(221) 0	(217) 2	(208) 23	(170) 81	(150) 121	(150) 42	(164) 2	(144) 0	(135) 0
Ouatagouna	(143) 0	(168) 0	(210) 0	(218) 0	(220) 3	(214) 14	(184) 66	(150) 68	(155) 29	(169) 2	(145) 0	(138) 0
Kogoni	(138) 0	(144) 0	(195) 0	(218) 0	(215) 4	(184) 30	(154) 111	(134) 139	(134) 62	(144) 5	(134) 0	(128) 0
Mopti	(147) 0	(162) 0	(209) 0	(220) 2	(210) 7	(187) 38	(155) 100	(136) 141	(136) 66	(148) 7	(135) 0	(129) 0
Keyes	(139) 0	(146) 0	(190) 0	(200) 0	(260) 4	(173) 58	(144) 129	(117) 179	(127) 114	(137) 12	(126) 0	(124) 0
Segou	(139) 0	(148) 0	(184) 0	(194) 2	(195) 14	(170) 59	(141) 141	(121) 188	(126) 88	(141) 8	(131) 0	(129) 0
Kita	(142) 0	(151) 0	(194) 0	(197) 2	(189) 21	(163) 112	(126) 197	(113) 274	(120) 172	(133) 32	(127) 0	(130) 0
Mahou	(145) 0	(158) 0	(187) 2	(179) 5	(180) 40	(147) 91	(129) 208	(119) 235	(119) 116	(139) 22	(130) 0	(132) 0
Bamako	(143) 0	(160) 0	(204) 1	(198) 5	(185) 33	(152) 106	(125) 195	(113) 256	(119) 157	(135) 27	(128) 0	(134) 0
Satadougou	(130) 0	(136) 0	(177) 0	(183) 2	(182) 13	(148) 151	(122) 232	(108) 308	(113) 243	(128) 55	(122) 0	(120) 0
Sikasso	(140) 0	(157) 0	(177) 4	(177) 21	(170) 66	(146) 129	(123) 213	(114) 279	(113) 179	(137) 52	(129) 0	(137) 0
Kalana	(142) 0	(143) 0	(178) 3	(182) 22	(169) 64	(145) 105	(122) 150	(108) 245	(112) 207	(133) 56	(127) 0	(128) 0

TABLE 4. DEPENDABLE PRECIPITATION AND POTENTIAL EVAPOTRANSPIRATION (PE in Brackets mm) FOR SELECTED STATIONS IN NIGER

	J	F	M	A	M	J	J	A	S	O	N	D
Agadez	(138) 0	(161) 0	(193) 0	(204) 0	(219) 0	(204) 3	(202) 24	(175) 54	(170) 4	(169) 0	(146) 0	(130) 0
N Gulgmi	(115) 0	(130) 0	(163) 0	(177) 0	(184) 0	(178) 1	(164) 27	(140) 72	(145) 4	(150) 0	(129) 0	(112) 0
Tanout	(137) 0	(155) 0	(187) 0	(197) 0	(208) 0	(193) 4	(175) 57	(146) 79	(155) 12	(167) 0	(143) 0	(124) 0
Dolbel	(153) 0	(163) 0	(204) 0	(211) 1	(220) 3	(210) 22	(180) 74	(143) 90	(140) 39	(172) 2	(148) 0	(140) 0
Zinder	(137) 0	(153) 0	(183) 0	(191) 0	(198) 4	(185) 22	(156) 101	(129) 146	(145) 39	(166) 1	(142) 0	(128) 0
Diffa	(137) 0	(135) 0	(169) 0	(190) 0	(199) 2	(178) 5	(150) 54	(126) 106	(138) 11	(153) 2	(141) 0	(123) 0
Toukounous	(169) 0	(173) 0	(205) 0	(212) 0	(232) 4	(220) 22	(184) 87	(144) 106	(150) 28	(182) 2	(171) 0	(147) 0
Ayorou	(155) 0	(165) 0	(206) 0	(213) 0	(228) 3	(217) 21	(183) 71	(145) 93	(155) 25	(178) 2	(150) 0	(143) 0
Tahoua	(183) 0	(186) 0	(212) 0	(220) 0	(232) 0	(225) 26	(186) 80	(155) 98	(161) 34	(189) 2	(186) 0	(155) 0
Tillabery	(158) 0	(167) 0	(196) 0	(208) 0	(212) 0	(210) 33	(175) 87	(140) 137	(140) 48	(177) 2	(156) 0	(143) 0
Niamey	(163) 0	(165) 0	(207) 0	(202) 0	(215) 0	(204) 44	(157) 109	(131) 152	(135) 64	(172) 4	(154) 0	(141) 0
Dogondoutchi	(159) 0	(158) 0	(187) 0	(190) 1	(210) 7	(195) 41	(155) 106	(132) 152	(137) 54	(164) 2	(143) 0	(137) 0
Maradi	(119) 0	(126) 0	(153) 0	(168) 0	(189) 9	(179) 33	(143) 126	(123) 193	(134) 62	(131) 0	(125) 0	(114) 0
Birni N Konni	(135) 0	(153) 0	(183) 0	(194) 1	(194) 10	(186) 46	(165) 95	(136) 159	(147) 64	(165) 2	(140) 0	(123) 0
Gaya	(133) 0	(148) 0	(177) 0	(178) 0	(194) 41	(187) 83	(147) 129	(119) 201	(130) 118	(150) 5	(133) 0	(126) 0

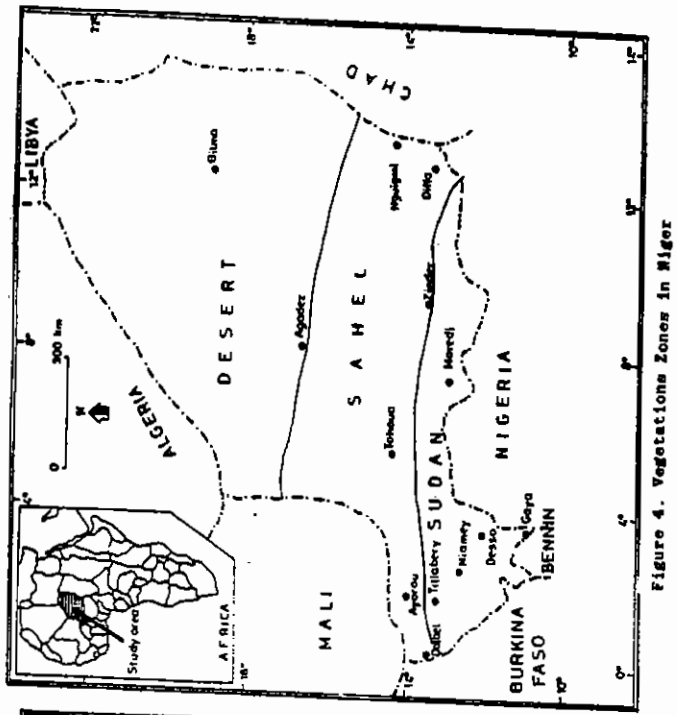

Figure 4. Vegetations Zones in Niger

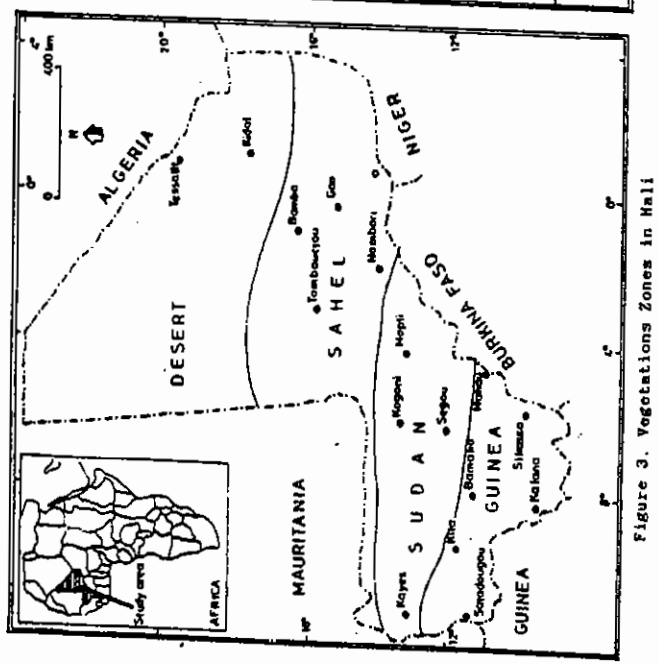

Figure 3. Vegetations Zones in Mali

beyond 16^0N have very deficient availability of moisture during the rainy season. The number of months of adequate moisture availability decreases from 6 months in the south west to zero in the desert region. On the basis of monthly MAI values in Table 5, Figure 5 was compiled.

Table 6 also shows the values of monthly MAI computed for 15 locations in Niger Republic. The availability of moisture for rainfed agriculture in Niger is much poorer than in Mali. It is only in the months of July and August that availability of moisture is adequate. It is very deficient from September to June. Unlike Mali, the number of months of moisture availability decreases from 4 months in the south-west to zero in the desert region. Figure 6 depicts the Niger region based on MAI in Table 6.

The classification of Mali shows that the country falls into four main moisture regions, the wet-dry in the southwest, the semi-arid, the arid and the very arid which constitutes more than half of the country. In the very arid region, all the months have an MAI of 0.33 or below. This region is absolutely unsuitable for rained agriculture. Tombouctou, Kidal and Tessalit are found in the very arid region. In the arid region are found Gao and Hombori which have one or two months with MAI of 0.34 or above. This region also has very limited suitability for rainfed agriculture. In contrast with the classification of Mali regions, the wet-dry region is absent in Niger. The latter falls into three regions - semi-arid in the south-west, the arid in the central part and the very arid wich covers about two-thirds of the country in the north.

A general examination of Figure 5 and 6 reveals that for rainfed agriculture, Mali has better availability of moisture than Niger because no part of the latter has 5 or more consecutive months with MAI of 0.34 or above. However, in the West African sub-region, Mali and Niger are among the driest of those where rainfed agriculture has limited suitability. This, the rivers Niger and Senegal are vital to the economy of both countries.

In Mali most of the commercial crops are cultivated in the valleys of rivers Niger and Senegal. The valleys of these rivers provide adequate and excessive moisture availability for the cultivation of rice and cotton (Fig. 7). Those crops which are grown without irrigation are found in the wet-dry regions where 5 or more consecutive months with MAI of 0.34 or above can be found. Sikasso region in the south is one of the most important areas where rainfed rice is grown since rice fits into the moisture availability range. Rainfed cotton is also grown in the same area and other parts of the wet-dry region as the growth cycle of cotton fits into the moisture availability range. Some cotton is grown in the semi-arid region but along the Niger valley at Segou, Moptie and Bamako where irrigation supplies the much needed moisture. Maize and groundnuts are widely grown in the wet-dry region where the moisture availability is suitable for their growth cycle. Maize, according to Purseglove (1972) grows best in areas with between 600-900 mm and where the availability of moisture is between 150 and 210 days. Sorghum and Millet are the main staple diet of the people and these are widely grown in the semi-arid region where different varieties are adjusted to the moisture availability of this region. The moisture availability for sorghum and millet are fairly adequate from July to September in the semi-arid region as shown in Tables 3 and 4. In the arid region non intensive subsistence millet and sorghum are grown. This region is predominantly

TABLE 5. MOISTURE AVAILABILITY INDEX (MAI) AT LOCATIONS IN MALI

Location	J	F	M	A	M	J	J	A	S	O	N	D	Classification	Criterion
Tessalit	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.12	0.03	0.00	0.00	0.00	Very arid	0 Month > 0,34
Kidal	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.20	0.05	0.00	0.00	0.00	Very arid	0 Month > 0,34
Bamba	0.00	0.00	0.00	0.00	0.00	0.03	0.14	0.31	0.05	0.01	0.00	0.00	Very arid	0 Month > 0,34
Toumbouctou	0.00	0.00	0.00	0.00	0.00	0.03	0.20	0.33	0.11	0.01	0.00	0.00	Very arid	0 Month > 0,34
Gao	0.00	0.00	0.00	0.00	0.00	0.04	0.23	0.44	0.09	0.01	0.00	0.00	Arid	1 Month > 0,34
Hombori	0.00	0.00	0.00	0.00	0.01	0.11	0.48	0.81	0.28	0.01	0.00	0.00	Arid	2 Month > 0,34
Ouanagouna	0.00	0.00	0.00	0.00	0.01	0.07	0.36	0.45	0.19	0.01	0.00	0.00	Arid	2 Month > 0,34
Kogoni	0.00	0.00	0.00	0.00	0.02	0.16	0.72	1.04	0.46	0.03	0.00	0.00	Semi-arid	3 Month > 0,34
Mopti	0.00	0.00	0.00	0.00	0.03	0.20	0.65	1.04	0.49	0.03	0.00	0.00	Semi-arid	3 Month > 0,34
Keyes	0.00	0.00	0.00	0.00	0.02	0.34	0.90	1.53	0.90	0.09	0.00	0.00	Semi-arid	4 Month > 0,34
Segou	0.00	0.00	0.00	0.01	0.07	0.35	1.00	1.55	0.70	0.06	0.00	0.00	Semi-arid	4 Month > 0,34
Kita	0.00	0.00	0.00	0.01	0.11	0.69	1.56	2.42	0.43	0.24	0.00	0.00	Semi-arid	4 Month > 0,34
Mahou	0.00	0.00	0.01	0.03	0.22	0.62	1.61	1.97	0.97	0.16	0.00	0.00	Semi-arid	4 Month > 0,34
Bamako	0.00	0.00	0.00	0.03	0.18	0.70	1.56	2.45	1.32	0.20	0.00	0.00	Semi-arid	4 Month > 0,34
Satadougou	0.00	0.00	0.00	0.01	0.07	1.02	1.90	2.85	2.15	0.43	0.00	0.00	Wet-dry	5 Month > 0,34
Sikasso	0.00	0.00	0.02	0.12	0.39	0.88	1.73	2.45	1.58	0.38	0.00	0.00	Wet-dry	6 Month > 0,34
Kalana	0.00	0.00	0.02	0.12	0.38	0.72	1.23	2.27	1.85	0.42	0.00	0.00	Wet-dry	6 Month > 0,34

TABLE 6. MOISTURE AVAILABILITY INDEX (MAI) AT LOCATIONS IN NIGER

Location	J	F	M	A	M	J	J	A	S	O	N	D	Classification	Criterion
Agadez	0.00	0.00	0.00	0.00	0.00	0.01	0.12	0.31	0.02	0.00	0.00	0.00	Very arid	0 Month > 0,34
N Guigmi	0.00	0.00	0.00	0.00	0.00	0.01	0.16	0.51	0.03	0.00	0.00	0.00	Arid	1 Month > 0,34
Tanout	0.00	0.00	0.00	0.00	0.00	0.02	0.33	0.54	0.08	0.00	0.00	0.00	Arid	1 Month > 0,34
Dolbet	0.00	0.00	0.00	0.00	0.01	0.10	0.41	0.63	0.28	0.01	0.00	0.00	Arid	2 Month > 0,34
Zinder	0.00	0.00	0.00	0.00	0.02	0.12	0.65	1.13	0.27	0.01	0.00	0.00	Arid	2 Month > 0,34
Diffa	0.00	0.00	0.00	0.00	0.01	0.03	0.36	0.84	0.08	0.01	0.00	0.00	Arid	2 Month > 0,34
Toukounous	0.00	0.00	0.00	0.00	0.02	0.10	0.47	0.74	0.19	0.01	0.00	0.00	Arid	2 Month > 0,34
Ayorou	0.00	0.00	0.00	0.00	0.01	0.10	0.38	1.64	0.16	0.01	0.00	0.00	Arid	2 Month > 0,34
Tahoua	0.00	0.00	0.00	0.00	0.00	0.12	0.43	0.63	0.21	0.01	0.00	0.00	Arid	2 Month > 0,34
Tillabery	0.00	0.00	0.00	0.00	0.00	0.16	0.50	0.98	0.34	0.01	0.00	0.00	Semi-arid	3 Month > 0,34
Niemy	0.00	0.00	0.00	0.00	0.00	0.22	0.69	1.16	0.47	0.02	0.00	0.00	Semi-arid	3 Month > 0,34
Dogondoutchi	0.00	0.00	0.00	0.01	0.03	0.21	0.68	1.15	0.39	0.01	0.00	0.00	Semi-arid	3 Month > 0,34
Maradi	0.00	0.00	0.00	0.00	0.05	0.18	0.88	1.57	0.46	0.00	0.00	0.00	Semi-arid	3 Month > 0,34
Birni N Konni	0.00	0.00	0.00	0.01	0.05	0.25	0.58	1.17	0.44	0.01	0.00	0.00	Semi-arid	3 Month > 0,34
Gaya	0.00	0.00	0.00	0.00	0.21	0.44	0.88	1.69	0.91	0.03	0.00	0.00	Semi-arid	4 Month > 0,34

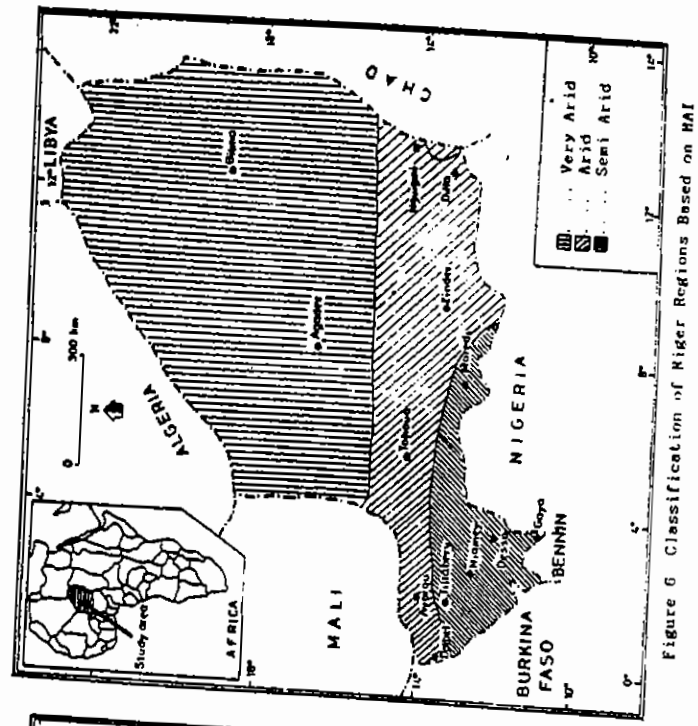

Figure 6 Classification of Niger Regions Based on MAI

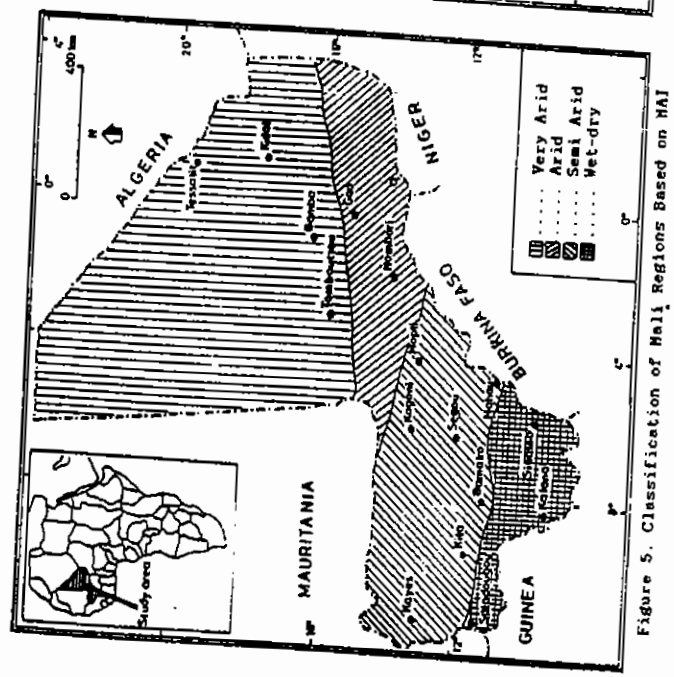

Figure 5. Classification of Mali Regions Based on MAI

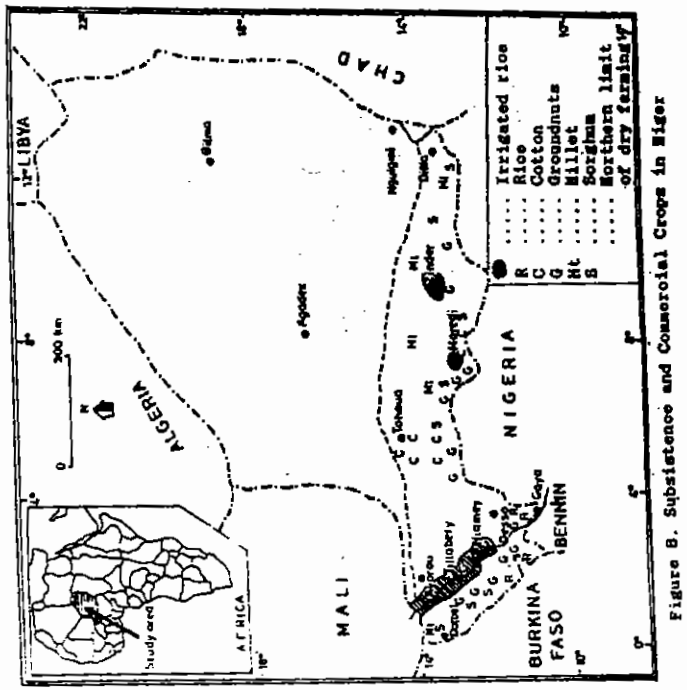

Figure 8. Subsistence and Commercial Crops in Niger

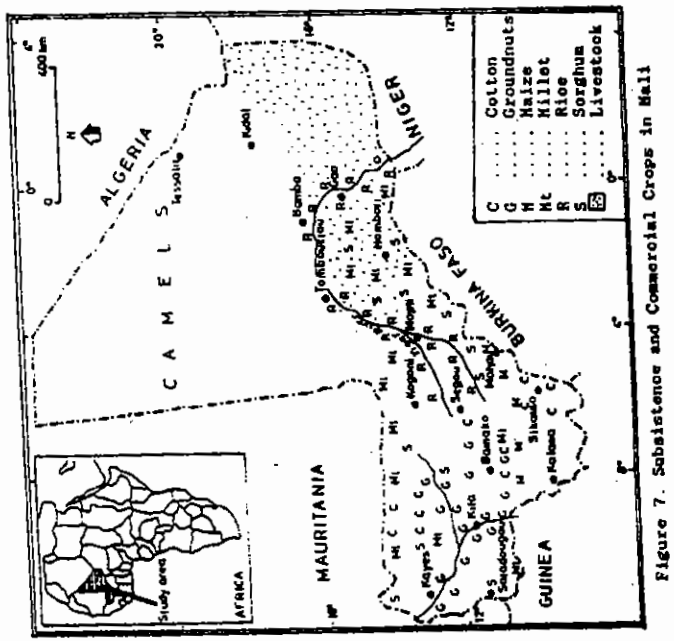

Figure 7. Subsistence and Commercial Crops in Mali

pastoral and nomadic grazing is practised. The moisture availability is so poor in this region that it is only the hardiest variety of millet that has a chance of surviving. In the very arid region, due to very deficient moisture availability, rainfed agriculture is practically impossible. Nomadism is the way of life of the people in the region.

In Niger Republic, the wet-dry region is non existent. As a result, all rice cultivation is done in the Niger river valley and in areas with ponds such as Maradi and Zinder (Figure 8). Cultivation of rainfed rice is absent since moisture availability necessary for its cultivation does not exist. Groundnut is the most important commercial crop grown in the country. It is grown in the south and southwest of the semi-arid region, in areas such as Maradi, Zinder and Tillabery. The growth cycle of groundnut fits perfectly into the moisture availability of this region. Cotton which produces best in the wet-dry region where moisture availability suits the growth cycle is grown in the semi-arid region in Maradi and Tahoua. At Tahoua cotton is on the verge of being expanded beyond the normal limit of dry farming and this is inadvisible since there is insufficiency of moisture availability. The moisture availability here is suitable for varieties of sorghum and millet which are widely grown in this region. The general aridity of Niger Republic militates againts the production of several crops including tobacco and sugar cane. In the northern Sahel, nomadism is the dominant way of life. As a result of the very arid nature of the areas beyond 15^0N, camel production is the main occupation. Livestock production is concentrated in the semi-arid regions.

CONCLUSION

The application of Hargreaves moisture availability indices to Mali and Niger shows that the format can be divided into four main moisture regions - wet-dry, semi-arid, arid and very arid while the latter encompasses three main moisture regions - semi-arid, arid and very arid. In terms of rainfed agriculture, Niger has less potential than Mali as the region with the best moisture availability (wet-dry) is absent. Consequently the production of certain crops such as tobacco and sugar cane whose MAI fits into wet-dry region is limited. The basin of river Niger which passes through both countries is heavily utilized for irrigation which provides adequate or excess moisture availability, but in Niger Republic, the cultivation of cotton at Tahoua and its environs is on the verge of being expanded beyond the normal limit of dry farming. This is not advisable. Cultivation of crops whose moisture availability does not fit into the growth cycle of a moisture region will lead to low economic returns.

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