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DRY-SPELL ANALYSIS FOR STUDYING THE SUSTAINABILITY OF RAIN-FED AGRICULTURE IN ETHIOPIA : THE CASE OF THE ARBAMINCH AREA

ANALYSE DU PHENOMENE DE SECHERESSE POUR L'ETUDE DE LA DURABILITE DE L'AGRICULTURE PLUVIEUSE EN ETHIOPIE – CAS DE LA REGION D'ARBAMINCH

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ABSTRACT

Several severe droughts (prolonged dry-spells) have occurred in Ethiopia in the last three decades that have caused considerable damage to rain-fed agriculture. Consequently, severe famines occurred which have greatly affected the lives of several people and also hampered the country's socio-economic development. In this paper, it has been tried to show the practical application of dry-spell analysis on long records of daily rainfall data (25 years) for justifying the failure of rain-fed agriculture in semi-arid and arid areas of the country. The case of the Arbaminch area is presented for two commonly grown crops (maize and cotton) at two sites – the Arbaminch State Farm (with clay-loam predominant soil type) and the Kola Shara Farmers' Farmland (with silt-clay predominant soil type). The frequency of occurrences of dry-spells of duration greater than 13 and 17 days, which already causes crop failure for maize and cotton crops, have a

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probability of 94% and 79% in the main rainy season at the Kola Shara Farmers' Farmland, respectively. The corresponding results for the Arbaminch State Farm are 16 and 21 days dry-spell duration and a probability of 70% and 45%, respectively. One could conclude from these results that rain-fed agriculture in the area is virtually impossible without supplementary irrigation. The procedure could be applied to different parts of the country and maps could be established for different crops. When irrigation is considered as a solution, there is problem of adequate water resources availability in semi-arid and arid areas of the country. Moreover, the wettest part of the country and more than 60% of the country's 3.5 million hectares potential irrigation land is found in the Ethiopian portion of the Nile River Basin. Therefore, Ethiopia will be forced to implement the small-scale, medium-scale and some of the large-scale irrigation projects identified in the various integrated watershed management studies of the Ethiopian portion of the Nile River Basin in order to avert the loss of lives of its citizens by frequently occurring famines. In this regard, sincere and sustainable consideration of the problem and full cooperation from the international community, the downstream riparian states of the Nile River Basin in particular, is essential.

RESUME

Plusieurs cas de phénomène de sécheresse (prolongée) ont été remarqués en Ethiopie au cours des trois dernières décennies, qui ont causé des dégâts considérables à l'agriculture pluvieuse. Comme conséquence de ce phénomène, des famines affreuses se sont produites qui ont affecté énormément la vie de nombreuses personnes et entravé le développement socio-économique du pays. Le rapport essaie de présenter l'application pratique de l'analyse de la sécheresse prolongée compte tenu des données quotidiennes recueillies au cours d'une longue période de 25 années pour justifier l'échec de l'agriculture pluvieuse dans les régions semi-arides et arides du pays. Le cas de la région d'Arbaminch est présenté en ce qui concerne la culture du maïs et du coton généralement entreprise dans deux sites – Exploitation Agricole de l'Etat d'Arbaminch (où prédomine le sol du type argile-terre franche) et Exploitation Agricole de Kola Shara (où prédomine le sol du type limon-argileux). La fréquence du phénomène de sécheresse prolongée d'une durée plus grande que 13 et 17 jours qui est déjà la cause de l'échec de la culture du maïs et du coton, a respectivement une probabilité de 94% et 79% dans la saison de pluie principale de l'Exploitation Agricole de Kola Shara. Les résultats qui correspondent à l'Exploitation Agricole de l'Etat d'Arbaminch représentent un phénomène de sécheresse prolongée de 16 et 21 jours et une probabilité de 70% et 45% respectivement. Sur la base de ces résultats, on peut donc conclure que l'agriculture pluvieuse de la région devient virtuellement impossible à moins qu'on ait recours à l'irrigation d'appoint. La procédure pourrait être appliquée à différentes régions du pays, et des cartes pourraient être établies pour différentes cultures. Quand l'irrigation est considérée comme une solution, le problème de disponibilité des ressources en eau se pose dans la région aride et semi-aride du pays. Cependant, la région la plus humide du pays et plus de 60% de la

superficie de 3,5 millions d'hectares se trouvent du côté ethiopien du bassin de Nil. Afin d'éviter la perte en vie humaine due à la fréquence des famines, l'Ethiopie sera donc obligée de mettre en oeuvre les projets d'irrigation de tailles petite, moyenne et quelques-uns des projets d'irrigation de grande taille identifiés dans diverses études de gestion intégrée de bassins versants de la région ethiopienne du Bassin de Nil. A cet égard, il est nécessaire d'étudier sincèrement le problème sur une base durable, et de disposer d'une collaboration absolue de la part de la communauté internationale et en particulier des Etats à l'aval du Bassin de Nil.

1. INTRODUCTION

The study area selected to illustrate the methodology is the Arbaminch area (Figure 1). Arbaminch is located at the floor of the southern part of the East African Rift Valley between $6^0$30'N to $6^0$08'N latitude and $37^0$33'E to $37^0$37'E longitude. The climate of the Arbaminch area is categorized as semi-arid. The mean annual rainfall, temperature, humidity, sunshine hours are about 750mm, 25^0C, 57%, 7.5 hours, respectively.

Two sites are considered in the analysis in the area. The first site is the Arbaminch State Farm (1000ha) with *clay-loam* predominant soil type and gently sloped plain topography. The second site is the Kola Shara farmers' farmland (150ha) with *silt-clay* predominant soil type and moderately sloped plain topography.

The occurrence of dry-spell has a particular relevance for rain-fed agriculture, as rainfall water is one of the major requirements for plant life in rain-fed agriculture. When spatial and/or temporal distribution of rainfall is erratic during the growing season, the crops may start to wilt and cause damage to crop yield. The extent of the damage depends on the frequency of occurrence of dry-spells of different duration, which depends on the soil moisture holding capacity and the type of crop. Hence, in addition to frequency analysis of dry-spells, assessment of soil-water-plant relationship is essential. In this regard two commonly grown crops in the area - Maize and Cotton - are considered in the analysis.

The rainfall pattern of the study area is bimodal type with a major peak in April and another smaller peak in October. There is more than 25 years (1973/74 - 1997/98) of recorded daily rainfall data at a meteorological station located in the Arbaminch State Farm. Long records of other required meteorological parameters are also available. There is also another first class meteorological station located at the Arbaminch Water Technology Institute (AWTI) campus that has records for the last 12 years. Since the two stations are very close to each other, the rainfall data analysis was done with out much difficulty. Therefore the quality of the rainfall data was carefully checked and corrected. Missing data were also completed.

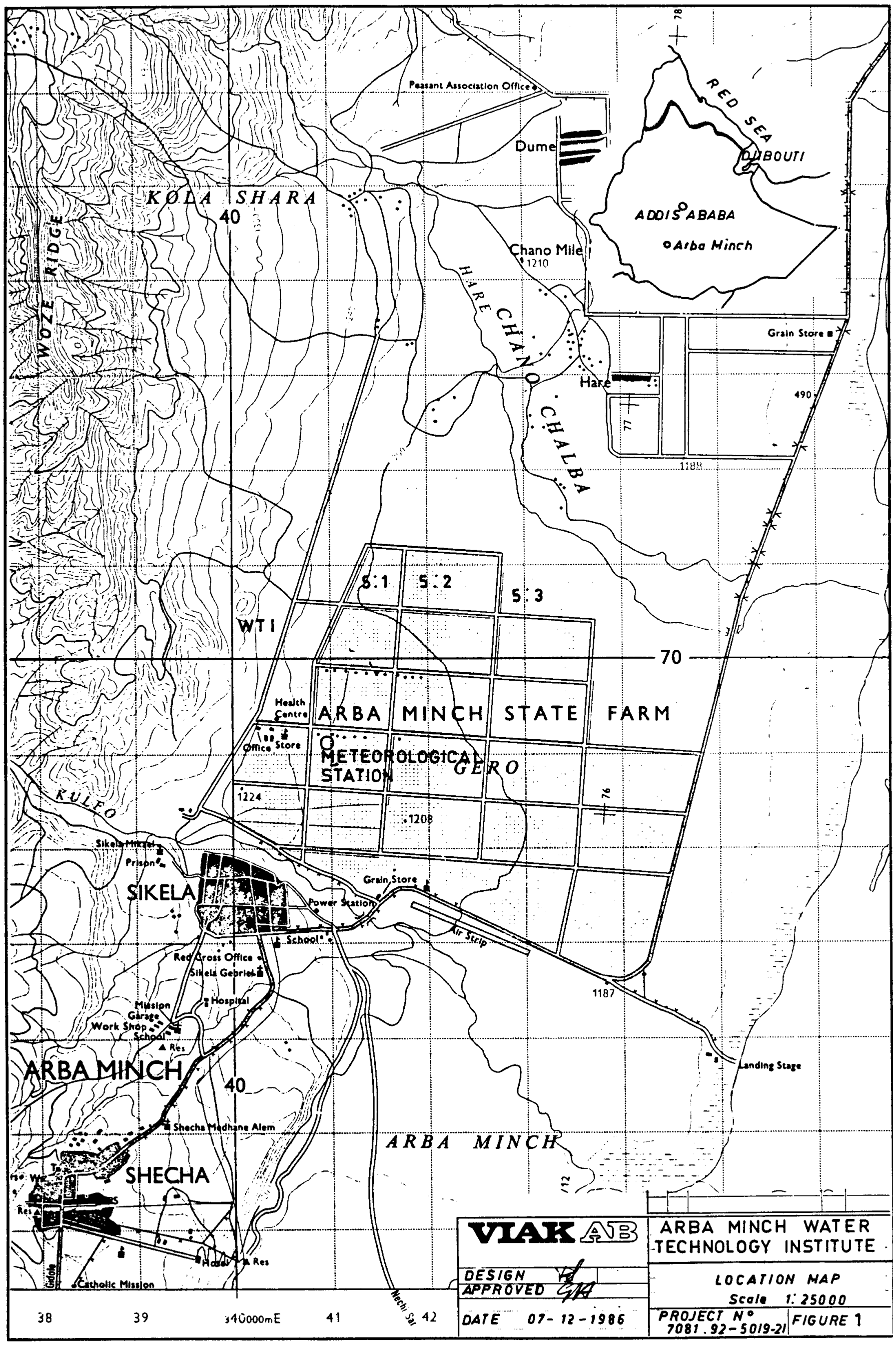

Figure 1. Location map of the Arbaminch Area (VIAK, 1987)

2. METHODOLOGY

The methodology primarily requires the following two major decisions:

(a) The mean length of the crop season or crop base period should be fixed. Based on the output from CROPWAT software and the long record rainfall trend, the crop base periods for maize and cotton are 100 days (April - July) and 150 days (April - September), respectively;

(b) The type of predominant soil and the moisture holding characteristics must be known. The Arbaminch State Farm has clay-loam predominant soil type and gently sloped plain topography (VIAK, 1987). The Kola Shara farmers' farmland has silt-clay predominant soil type and moderately sloped plain topography (Determined by laboratory test).

2.1 Frequency Analysis of Dry-Spells

The occurrence of dry-spells of different duration in the crop seasons must be analyzed using frequency analysis of daily rainfall data. The procedure of the frequency analysis is similar to that applied in the establishment of flow duration curve for stream flow (Shaw, 1993). However, the procedure is quite different from those analyses involving statistical analysis of low rainfall values only. In fact statistical analysis on low rainfall values is nonsense since the lower limit of rainfall is deterministically known to be zero.

In the Y years of records, the number of times i that a dry-spell of duration t days occurs will be counted. Then the number of times I that a dry-spell of duration longer than or equal to t occurs is computed through accumulation. The number of days within a crop season on which a dry-spell of duration t could start is computed using n = m + 1 - t, where m is the total number of days of a crop season. The total possible number of starting days is N = n*Y. Subsequently the probability p that a dry-spell starts on a certain day within the crop season is given by :

$$p = \frac{I}{N} \tag{1}$$

Thus, the probability q that a dry-spell of duration longer than t does not occur at a certain day in the crop season is given by :

$$q = (1 - p) = \left(1 - \frac{I}{N}\right) \tag{2}$$

The probability Q that a dry-spell of duration longer than t does not occur during an entire crop season is given by :

$$Q = \left(1 - \frac{I}{N}\right)^n \qquad (3)$$

Finally, the probability that a dry-spell of duration longer than **t** does occur at least once in a crop season is given by :

$$P = (1 - Q) = 1 - \left(1 - \frac{I}{N}\right)^n \qquad (4)$$

In interpreting the results of equations (1 to 4), information about soil - water - plant relationship is required to fix the duration of dry-spells (t). For the Ethiopian condition, the author recommends the following general probability conditions. If P(t) is greater than 80%, rain-fed agriculture is almost impossible in the area. For 20%≤P(t)£80%, rain-fed agriculture may be possible with supplementary irrigation in the area. For P(t)≤20% rain-fed agriculture may be possible without supplementary irrigation in the area.

2.2 Assessment of Soil - Water - Plant Relationship

The purpose of the assessment of soil-water-plant relationships is primarily to estimate the mean frequency of irrigation. This will in turn determines the dry-spell duration longer than which will cause damage to crop yield.

The crop water requirements of the selected crops for a known soil type and characteristics must be determined. Use of software like CROPWAT is recommended. The crop water requirements needed here is the consumptive use of plants (ET_{CROP}). ET_{CROP} could be determined using empirical methods like the *modified Penman-Montieth method, Jensen-Haise method, Hargreaves method, Thornthwaite method, Balney-Criddle method, Hargreaves class A pan evaporation method, etc.*

The frequency of irrigation is then obtained using (FAO, 1992) :

$$I = \frac{(p * S_a) * D}{ET_{CROP}} \qquad (5)$$

Where :

p = fraction of total available soil water which can be used by the crop without affecting its transpiration and/or growth;

S_a = total available soil water or moisture (S_{FC} - S_W) in mm/m;

S_{FC} = available soil water or moisture at field capacity in mm/m;

S_W = available soil water or moisture at permanent wilting point in mm/m;
D = depth of root zone of a crop (m);
ET_{CROP} = consumptive crop water requirements.

Not all the water that is held in the root zone between S_W and S_{FC} is available to the crop (Figure 2). The depth of water that is readily available to the crop is $p*S_a$ and it is related to the depth of application by :

$$d = \frac{(p * S_a) * D}{f_a} \tag{6}$$

Where f_a = water application efficiency (fraction). The value of $(p*S_a)$ will vary with the level of evaporative demand. Since the evaporative demand varies with the growing stages of crops, $(p*S_a)$ will be different with different growing stages of crops. According to FAO (1992), when ET_{CROP} is low (3 mm/day), the crop will transpire at its maximum rate to a soil-water depletion greater than that when ET_{CROP} is high (.8mm/day).

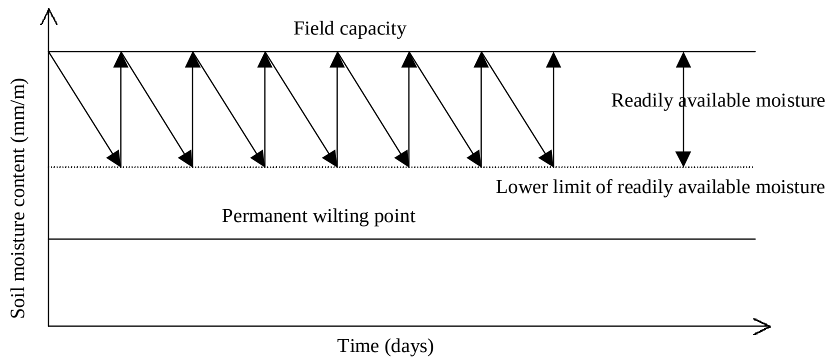

Figure 2. Frequency of Irrigation

3. RESULTS AND DISCUSSION

Based on the above procedure, the frequency analysis of the two crops was done. The results are presented in Tables 1 and 2 and Figures 3 and 4.

Based on the above procedures, the mean frequency of irrigation for maize crop are estimated to be 13 and 16 days for the Kolla Shara farmers' land and

Table 1. Frequency Analysis of Different Duration of Dry-spells for Maize Crop

Spell duration t (days)	No. of spells i	Accum. spells I	Days per season n=100+1-t	Total No. of days N=n*25	p=I/N	q=1-p	P=1-(q)^n
5	196	768	96	2400	0.32	0.68	1.00
6	144	572	95	2375	0.24	0.76	1.00
7	103	428	94	2350	0.18	0.82	1.00
8	78	325	93	2325	0.14	0.86	1.00
9	64	247	92	2300	0.11	0.89	1.00
10	51	183	91	2275	0.08	0.92	1.00
11	34	132	90	2250	0.06	0.94	1.00
12	27	98	89	2225	0.04	0.96	0.98
13	18	71	88	2200	0.03	0.97	0.94
14	13	53	87	2175	0.02	0.98	0.88
15	10	40	86	2150	0.02	0.98	0.80
16	7	30	85	2125	0.01	0.99	0.70
17	7	23	84	2100	0.01	0.99	0.60
18	6	16	83	2075	0.01	0.99	0.47
19	5	10	82	2050	0.00	1.00	0.33
20	4	5	81	2025	0.00	1.00	0.18
21	1	1	80	2000	0.00	1.00	0.04
22	0	0	79	1975	0.00	1.00	0.00
23	0	0	78	1950	0.00	1.00	0.00
24	0	0	77	1925	0.00	1.00	0.00
25	0	0	76	1900	0.00	1.00	0.00
26	0	0	75	1875	0.00	1.00	0.00
27	0	0	74	1850	0.00	1.00	0.00
28	0	0	73	1825	0.00	1.00	0.00
29	0	0	72	1800	0.00	1.00	0.00
30	0	0	71	1775	0.00	1.00	0.00

the Arbaminch State Farm, respectively. For cotton crop the corresponding values are 17 and 21 days. These values are closer to those gathered through questionnaires to the farmers' and farm experts.

The crop water requirements for maize and cotton crops have been determined using CROPWAT software (FAO, 1991). Climatic data input to CROPWAT for the Arbaminch area is presented in Table 3. The resulting potential evapotranspiration determined by CROPWAT based on the Penman-Montieth method is presented in Table 4. Then, the crop water requirements are presented in Tables 5 and 6 for maize and cotton, respectively.

Table 2. Frequency Analysis of Different Duration of Dry-spells for Cotton Crop

Spell duration t (days)	No. of spells i	Accum. spells I	Days per season n=100+1-t	Total No. of days N=n*25	p=I/N	q=1-p	P=1-(q)^n
5	255	986	146	3650	0.27	0.73	1.00
6	182	731	145	3625	0.20	0.80	1.00
7	132	550	144	3600	0.15	0.85	1.00
8	96	419	143	3575	0.12	0.88	1.00
9	79	324	142	3550	0.09	0.91	1.00
10	62	246	141	3525	0.07	0.93	1.00
11	45	184	140	3500	0.05	0.95	1.00
12	34	139	139	3475	0.04	0.96	1.00
13	24	105	138	3450	0.03	0.97	0.99
14	18	81	137	3425	0.02	0.98	0.96
15	15	63	136	3400	0.02	0.98	0.92
16	9	48	135	3375	0.01	0.99	0.86
17	8	39	134	3350	0.01	0.99	0.79
18	6	31	133	3325	0.01	0.99	0.71
19	5	25	132	3300	0.01	0.99	0.63
20	5	20	131	3275	0.01	0.99	0.55
21	2	15	130	3250	0.00	1.00	0.45
22	1	13	129	3225	0.00	1.00	0.41
23	1	12	128	3200	0.00	1.00	0.38
24	1	11	127	3175	0.00	1.00	0.36
25	1	10	126	3150	0.00	1.00	0.33
26	1	9	125	3125	0.00	1.00	0.30
27	1	8	124	3100	0.00	1.00	0.27
28	1	7	123	3075	0.00	1.00	0.24
29	1	6	122	3050	0.00	1.00	0.21
30	1	5	121	3025	0.00	1.00	0.18
31	1	4	120	3000	0.00	1.00	0.15
32	1	3	119	2975	0.00	1.00	0.11
33	1	2	118	2950	0.00	1.00	0.08
34	1	1	117	2925	0.00	1.00	0.04

From Figure 2, for maize crop, the probabilities that a dry-spell of duration longer than 13 and 16 days does occur at least once in a crop season are 94% and 70% at the Kolla Shara farmers' farmland and Arbaminch State Farm, respectively. From Figure 3, for cotton crop, the probabilities that a dry-spell of duration longer than 17 and 21 days does occur at least once in a crop season are 79% and 45% at the Kolla Shara farmers' farmland and Arbaminch State Farm, respectively.

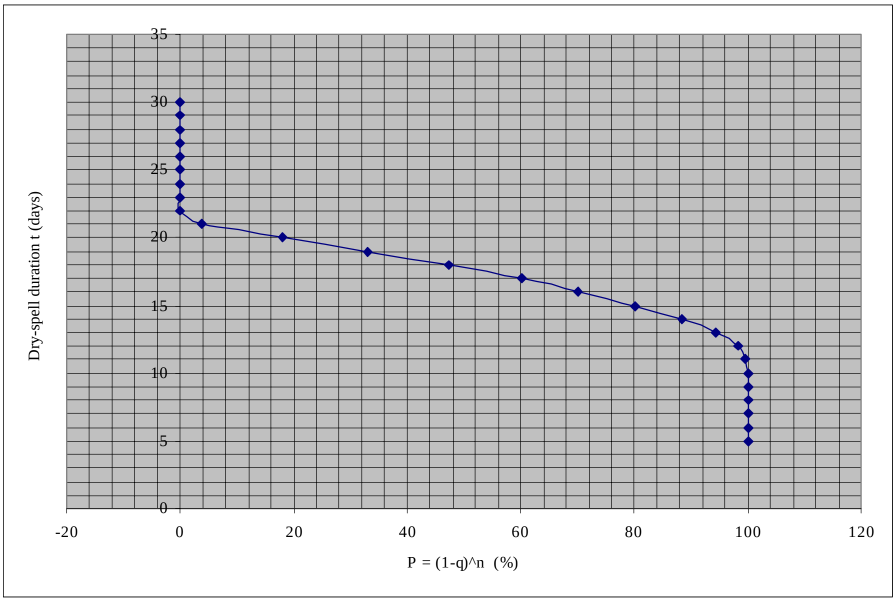

Figure 3. Dry-spell probability curve for maize crop

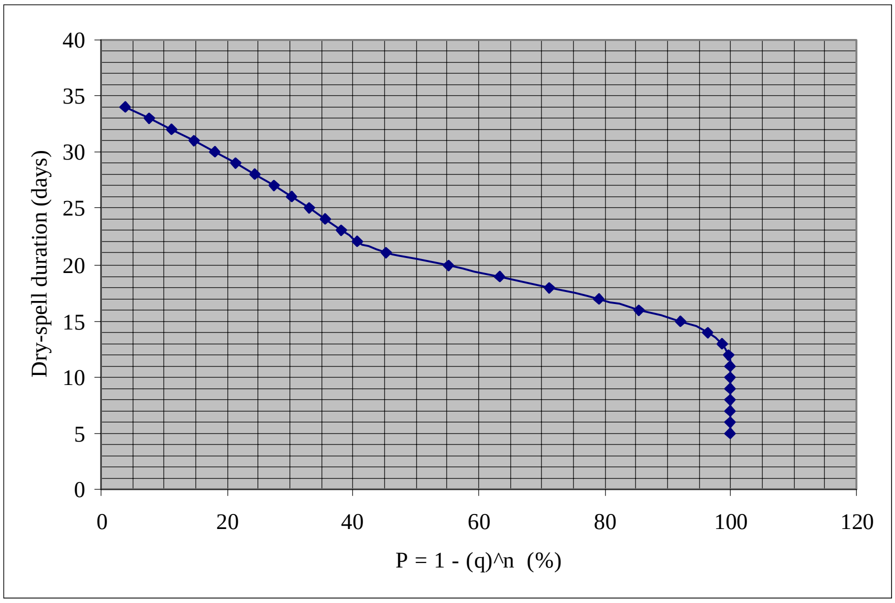

Figure 4. Dry-spell probability curve for cotton crop

Table 3. Meteorological data for Arbaminch (1973 - 1994)

Station Name = Arbaminch, Altitude = 1200m, Latitude = 6.05^{0}N, Longitude = 38^{0}E										
Month	Average rainfall (mm)	Temperature (^{0}C)			Relative Humidity (%)			Avg. Daily Wind Speed		Sunshine Hours
		MAX.	MIN.	Avg.	MAX.*	MIN.*	Avg.**	(km/hr)	(m/sec)	
January	23	31.8	16.7	24.2	73	36	49	3.60	1.0	9.2
February	32	32.6	18.2	25.4	71	34	49	3.96	1.1	8.5
March	56	32.9	18.6	25.8	72	33	49	4.68	1.3	8.1
April	114	31.1	18.6	24.9	84	43	61	4.68	1.3	7.1
May	131	28.8	18.3	23.6	81	56	65	5.76	1.6	7.7
June	61	27.9	18.3	23.1	79	52	61	6.12	1.7	6.7
July	44	27.4	18.1	22.8	83	47	63	5.76	1.6	4.5
August	52	28.5	18.2	23.4	79	47	60	5.76	1.6	5.5
September	72	30.2	18.1	24.2	78	45	59	5.04	1.4	6.9
October	92	30.3	17.5	23.9	78	48	61	3.96	1.1	7.9
November	54	31.0	16.4	23.7	72	44	57	3.60	1.0	9.2
December	24	31.7	15.7	23.7	72	36	52	3.24	0.9	8.4
Total	753									

* = For the period 1973 - 1994 and ** = for the period 1987 - 1995 only!

Table 4. Potential evapotranspiration obtained from CROPWAT

Climate Station: Arbaminch			
Month	ET_0 (mm/day)	Rainfall (mm/month)	Effective Rainfall (mm/month)
January	4.5	28.6	27.3
February	4.8	31.1	29.6
March	5.2	58.5	53.1
April	4.7	134.3	105.4
May	4.6	155.4	116.8
June	4.3	66.0	59.0
July	3.8	47.6	44.0
August	4.3	55.6	50.6
September	4.6	74.6	65.7
October	4.5	100.8	84.6
November	4.5	53.6	49.0
December	4.2	23.6	22.7
Year Total	1642.3	829.6	707.6
Effective Rainfall with USBR method			

One could conclude from these results that rain-fed agriculture in the area is virtually impossible without supplementary irrigation. The procedure could be applied to different parts of the country and maps could be established for different crops. When irrigation is considered as a solution, there is problem of adequate water resources availability in semi-arid and arid areas of the country.

Ethiopia, with a geographical area of about 113 million $(km)^2$, has been affected frequently by severe droughts (prolonged dry-spells) in the last four decades. This is because the large part of the country is categorized as drought prone areas (Figure 5). About 60% of the area is potentially cultivable, with only 15% currently utilized (CSA, 1995). Moreover, the country has more than 3.5 million hectares potential irrigable land with less than 3%. The country has also about 120 Bm^3 surface water and about 2.6 Bm^3 groundwater resources potential (MOWR, 1998). But the spatial and temporal variation of the water resource is erratic. Therefore it is a paradox that the world knows about Ethiopia by its recurring droughts linked with famine rather than by its vast natural resources. This impression is however largely due to media images.

4. CONCLUSIONS AND RECOMMENDATIONS

As it has been discussed in the previous section rain-fed agriculture in the Arbaminch area is virtually impossible without supplementary irrigation. It can

Table 5. Crop water requirements for maize crop obtained from CROPWAT

Crop Evapotranspiration and Irrigation Requirements								
Crop: Maize, Climate Station: Arbaminch, Planting date: 1 April								
Month	Decade	Stage	Coeff. K_C	ET_{CROP} mm/day	ET_{CROP} mm/decade	Eff. Rain mm/decade	$IRR_{eq.}$ mm/day	$IRR_{eq.}$ mm/decade
April	1	Initial	0.45	2.20	22.0	29.7	0.00	0.0
April	2	Initial	0.45	2.13	21.3	36.1	0.00	0.0
April	3	Develop.	0.55	2.57	25.7	37.1	0.00	0.0
May	1	Develop.	0.74	3.45	34.5	39.3	0.00	0.0
May	2	Develop.	0.94	4.32	43.2	40.9	0.23	2.3
May	3	Develop.	1.08	4.90	49.0	33.8	1.51	15.1
June	1	Develop/mid	1.13	5.01	50.1	25.4	2.47	24.7
June	2	Mid	1.13	4.90	49.0	17.7	3.14	31.4
June	3	Mid	1.13	4.71	47.1	16.7	3.05	30.5
July	1	Mid	1.13	4.44	44.4	15.7	2.88	28.8
July	2	Late	1.07	4.00	40.0	14.7	2.53	25.3
July	3	Late	0.96	3.73	37.3	15.4	2.19	21.9
August	1	Late	0.84	3.45	17.3	8.1	1.84	9.2
Total					480.9	330.5		189.2

Table 6. Crop water requirements for cotton crop obtained from CROPWAT

Crop Evapotranspiration and Irrigation Requirements								
Crop: Cotton, Climate Station: Arbaminch, Planting date: 1 April								
Month	Decade	Stage	Coeff. K_C	ET_{CROP} mm/day	ET_{CROP} mm/decade	Eff. Rain mm/decade	$IRR_{eq..}$ mm/day	$IRR_{eq..}$ mm/decade
April	1	Initial	0.50	2.44	24.4	29.7	0.00	0.0
April	2	Initial	0.50	2.37	23.7	36.1	0.00	0.0
April	3	Initial	0.50	2.35	23.5	37.1	0.00	0.0
May	1	Develop.	0.56	2.58	25.8	39.3	0.00	0.0
May	2	Develop.	0.66	3.07	30.7	40.9	0.00	0.0
May	3	Develop.	0.78	3.51	35.1	33.8	0.12	1.2
June	1	Develop.	0.89	3.92	39.2	25.4	1.38	13.8
June	2	Develop.	0.99	4.32	43.2	17.7	2.55	25.5
June	3	Mid	1.05	4.38	43.8	16.7	2.71	27.1
July	1	Mid	1.05	4.13	41.3	15.7	2.56	25.6
July	2	Mid	1.05	3.92	39.2	14.7	2.45	24.5
July	3	Mid	1.05	4.10	41.0	15.4	2.56	25.6
August	1	Mid	1.05	4.32	43.2	16.1	2.70	27.0
August	2	Mid/late	1.04	4.40	44.0	16.9	2.72	27.2
August	3	Late	0.99	4.35	43.5	18.5	2.49	24.9
September	1	Late	0.94	4.22	42.2	20.2	2.19	21.9
September	2	Late	0.88	4.07	40.7	21.9	1.88	18.8
September	3	Late	0.83	3.79	37.9	24.0	1.39	13.9
Total					662.2	440.1		277.2

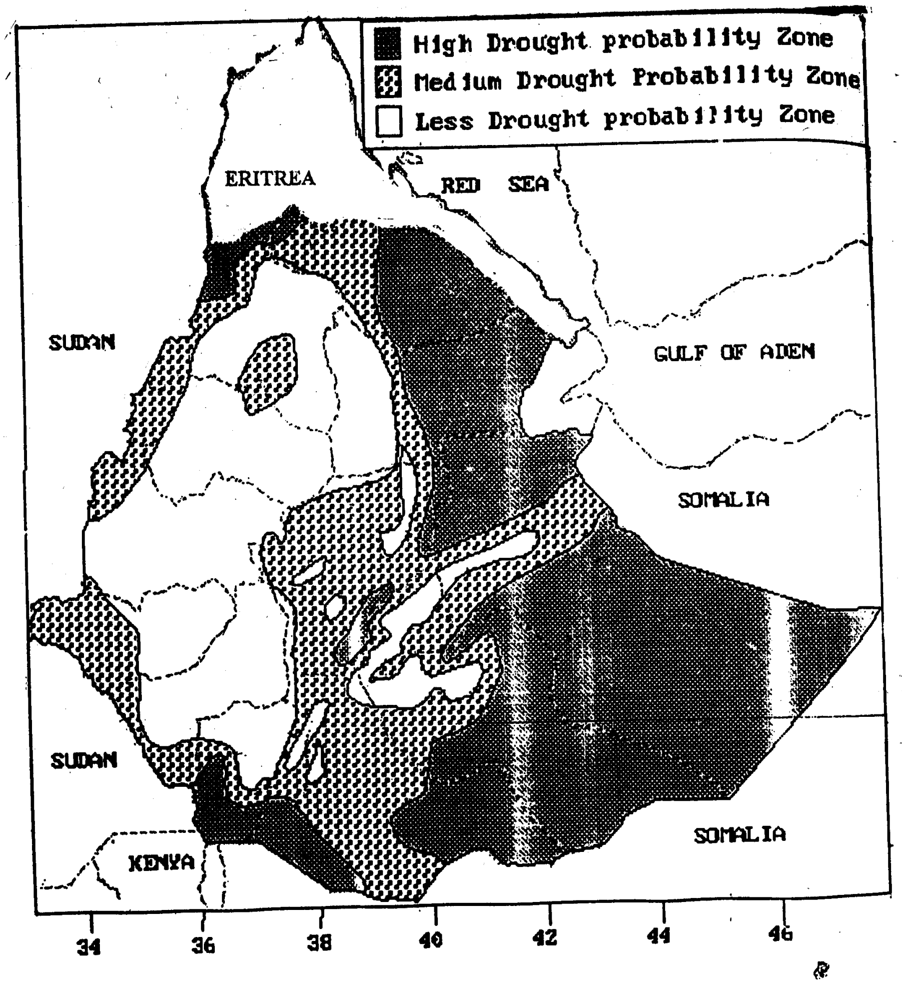

Figure 5. Drought Probability Map of Ethiopia (NMSA, 1996)

also be concluded that farmlands having the same climatic data could have different probabilities of dry-spells if their soil type and characteristics are different. This can be clearly observed from the results obtained for the maize and cotton crops for the two selected sites in the Arbaminch area. In fact, in several parts of Ethiopia, long daily rainfall records is not be available. However, The methodology could be applied to those parts of the country that do have the data.

The result shows also almost every year dry-spell duration that causes damage to crop yield occurs in the area. This will justify the failure of rain-fed agriculture in Ethiopia even though droughts (prolonged dry-spells) may not occur. Therefore the “Green Famine Dilemma” in Ethiopia is justified by the presented dry-spell analysis.

The dry-spell analysis presented in this paper has the following purposes :

(i) It can be used for proper policy making in the prioritization of irrigation projects in the country;

(ii) It can be used to justify whether ran-fed agriculture is sustainable or not in different parts of the country;

The majority of the country’s 3.5 Mha irrigation potential (more than 60%) is located in the Ethiopian portion of the Nile River Basin (Figure 6). Moreover, as can be seen from Figure 5, the wettest part of the country is also found in the Ethiopian portion of the Nile River Basin. Therefore, Ethiopia will be forced to implement the small-scale, medium-scale and some of the large-scale irrigation projects identified in the various integrated watershed management studies of the Ethiopian portion of the Nile River Basin in order to avert the loss of lives of its citizens by frequently occurring famines. In this regard, sincere and sustainable consideration of the problem and full cooperation from the international community, the downstream riparian states of the Nile River Basin in particular, is essential.

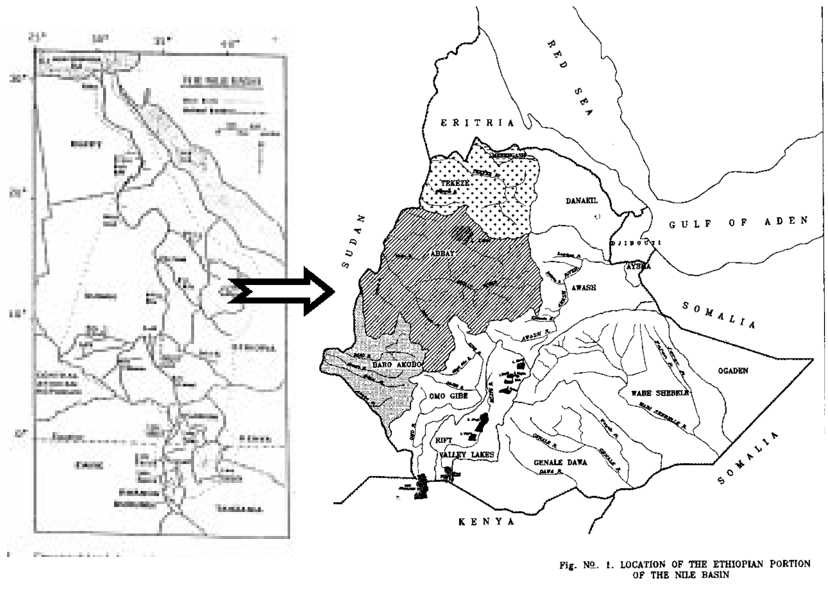

Figure 6. Location Map of the Nile River Basin (After Tefera, 1997)

5. REFERENCES

Central Statistical Authority (CSA), 1995. The 1994 population and housing census of Ethiopia, Office of population and housing census commission, Addis Ababa, Ethiopia

FAO, 1991. CROPWAT Version 5.7, FAO software library, Irrigation Planning and Management Tool, Rome.

FAO, 1992. Crop Water requirements. FAO Irrigation and Drainage Publications No 24, Rome.

Ministry of Water Resources (MOWR), 1998. Federal water resources policy draft document, Federal water policy and strategy development project office, Addis Ababa, Ethiopia.

National Meteorological Services Agency (NMSA), 1996. Climatic and agroclimatic resources of Ethiopia. Meteorological research report series. Vol. 1, No 1.

Shaw. E. 1993. Hydrology in practice. Chapman and Hall, London.

Tefera Woudneh. 1997. Water Demand Scenario in the Ethiopian Portion of the Nile Basin. Vth Nile 2002 conference, Addis Ababa, Ethiopia.

VIAK, 1987. Arbaminch Water Technology Institute Irrigation and Drainage Final Report. UNCDF, ETH/85/C01. Addis Ababa, Ethiopia.

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Abebe Belachew

2000

Prize - Winning paper for
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Late Dr. Hassan M. Ismail was a highly respected national and international personality. He was Professor of Hydraulics and Dean of Faculty of Engineering, Cairo University. Later he became the President of Cairo University, President of the Academy of Science, Egypt and Minister of Higher Education. He was also the President of the leading consultancy firm PACER and member of several international organizations, associations and societies. Dr. Ismail Hassan dedicated his entire life to the development of science and to educating generations of irrigation and drainage engineers in Egypt. He firmly believed in the role of ICID in ensuring international cooperation in the advancement of the world knowledge and experience in irrigation and drainage. Dr. Ismail had a great faith in young professionals, especially from Africa to carry out creative work in water management and sustainable development in irrigated agriculture.

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The 5th Dr. Hassan Ismail Memorial International Award, 2000 has been awarded to Mr. Abebe Belachew Belete for his paper titled "Dry-Spell Analysis for Studying the Sustainability of Rain-Fed Agriculture in Ethiopia: The Case of the Arbaminch Area" which he presented at the 8th Nile 2002 Conference held in Addis Ababa, Ethiopia in June 2000.

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