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PATTERNS OF CROP ASSOCIATION IN THE PEASANT SECTOR OF ETHIOPIA

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Twenty-nine crops reported in 78 Awrajas were subjected to principal component analysis in order ;to explore the underlying crop structure in the peasant sector. Ten components with eigenvalues ≥1 were extracted. These components, which represent ten crop clusters, accounted for 69% of the variance of the original data matrix. Although the method produced distinct crop clusters, it did not totally overcome the mapping problems faced in crop-combination studies as certain Awrajas scored high on more than one component. Mapping the component scores, however, revealed that the crop clusters identified have highest concentration in the areas where their respective rainfall and temperature requirements are adequately met. But comparison with similar studies showed that the crop clusters identified here differ markedly from crop clusters identified by those studies.

INTRODUCTION

Ethiopia is an agricultural country with more than 85% of its population engaged in farming. At a factor cost of 1980/81, the agricultural sector contributed 43.2% to the GDP in 1987/88. Moreover, it accounted for more than 90% of the country's foreign exchange earnings. Agriculture continues to hold central position in the Ethiopian economy, and its percentage share in the GDP decreased by only 3 % over the 1974/75--1986/87 period (FAO 1986:118).

The peasant sector is the leading farming sector in Ethiopia, and it accounted for 95.4% of the cropland and 94.8% of the agricultural

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production in 1984/85. The remaining proportion was shared by Cooperatives, State Farms and Settlement farms which accounted respectively for 1.4%, 2.8%, and 0.4% of the cropland and 1.4%, 3.6% and 0.2% of the agricultural production (Dessalegn 1990:101).

Most of the production activity in the peasant sector is subsistence. The marketed proportion rarely exceeds 20% as peasants retain up to 80% of their produce for home consumption and seeds (FAO 1986:77). Peasants cultivate a large number of crops ; in some Awrajas (Provinces) like Chebo and Guraghe up to 20 types of crops are cultivated. Bekure (1983) stated that concern for food security coupled with favorable agro-climatological conditions appear to have encouraged peasants to cultivate varieties of crops

The abundance of crop types and their seemingly random distribution tends to give the impression that the subsistence economy is a haphazard and disorderly system of land-use. Despite its disorderly appearançe, however, relationships may exist among the various crop occurrences (Henshel and King 1966). These relationships may not be easily or readily discernible, but they may be identified if they are carefully scrutinized using appropriate techniques. With the help of multivariate techniques, a search for basic crop structures underlying the seemingly haphazard pattern of crop occurrence in the peasant sector is made in this paper.

Objectives of the Study

An understanding of crop association is very essential for proper land-use planning. This paper hopes to make a modest contribution to this aim by identifying basic crop associations and their spatial patterns in the peasant sector. With this in mind, the paper has the following objectives:

1. To identify crop clusters on the basis of their spatial covariance,

2. To portray the spatial pattern of the crop clusters identified,and to evaluate their distribution by relating their spatial distribution to their rainfall and temperature requirements, both of which are related to altitude, and affect the range of crops that can be successfully cultivated in any place (Hunting Technical Service 1974:24), and

3. To compare the crop clusters identified in this study with similar studies done earlier.

Evolution of Crop Patterns

Agriculture is influenced by a host of factors and crop patterns are complex both in nature and causation. Generally, crop patterns evolve in response to physical--soil, climate, relief, etc.--and socio-economic and cultural factors (Ilbery 1979; Knowles and Wareing 1976). Since this study is concerned with the spatial patterns of crop association at Awraja level, many of which show great diversity in terms of their socio-economic and cultural characteristics, the attention is focused on the relationship between crop associations and environmental conditions.

Agricultural production process, whether it is crop cultivation or livestock raising, is essentially a biological process.The biological nature of the production process provides the link between the physical environment and the spatial structure of crops. Since there are important environmental thresholds for each crop, many environmental factors show close relationship with certain agricultural enterprises as crops with similar environmental requirements concentrate in areas that best meet their environmental requirements. Some authorities, in fact, accord physical components top priority as explanatory variables in analyzing the spatial structure of crops. Haining (1978:494), for instance, found that wheat cultivation varied directly with rainfall distribution, and he argued that spatial trends in cropping should be analyzed within the process-response context. Thus subject to man's willingness and ability to ameliorate physical constraints, spatial variations in the physical environment place limits on the spatial distribution of crops.

Since Ethiopian peasants are largely oriented to subsistence production, and since they rely on rainfall for their moisture supply,it may be postulated that patterns of crop distribution are primarily governed by environmental conditions. Each peasant would tend to choose those crops that are best suited to his local environment on the basis of which he would also decide how intensively the chosen crop or crop mix should be cultivated. As each peasant grows those crops that are best suited to his local conditions, spatial variations in crops may be expected to replicate spatial variations in environmental conditions.

Earlier Studies

In recent years, the recurrent famine in the country has stimulated individuals and organizations to study the Ethiopian agriculture in some details. The primary aim of these studies appears to provide sound foundation for the planning of agricultural development. Some of these studies have attempted to identify crop zonation or farming systems. The bases of classification range from environmental conditions, farm types or organizations to crop combinations.

Traditionally Ethiopian peasants refer to five broad agro-climatological zones, namely Bereha(<800 m), Kolla(800-1500 m), Woyna Dega(1500-2300 m), Dega(2300-3000 m) and Wurch(>3000 m). Even though these zones are identified by altitude at present, Ethiopian peasants identify them by the dominant crops that grow in each zone as well as their suitability for farming (Dessalegn 1988).

Altitude, through its influence on rainfall and temperature, is a primary factor which determines the type of crops that can be grown in an area. Thus, although the traditional zonation may be imprecise, it may form a basis for more refined zonation (FAO 1986a:22); in fact, the Hunting

Technical Service (1976) in its study of Tigray tried to group crops on the basis of altitude (see Table 8). Seen in this way, the traditional zones may be regarded as broad crop combination zones.

Westphal (1975:83) on the other hand refers to four types of agricultural systems whose border lines are "not always clear" due to "many transitions and great diversity within each of these systems". The farming systems identified are the Seed Farming Complex, the Enset Complex, the Shifting Cultivation and the Pastoral Complex. Westphal appears to base his classification mainly on the labor process involved, technology used and the ultimate aim of production (Dessalegn 1988:5).

In a study of land evaluation for the Land-use Planning Department of the Ministry of Agriculture, a group of FAO/UNDP (1984a:13) experts identified 20 crop combinations for the rainfed agriculture of the country on the basis of "approximate similar environmental requirements". These crop combinations are listed in Table 6. In another study, the Ethiopian Highland Reclamation Study, FAO (1986a:24) adopted a very broad, three-zone division primarily on the bases of soils, levels of degradation, rainfall, length of growing period, major farming systems and agricultural potential. Accordingly, the country is divided into High Potential Cereal (HPC), Low Potential Cereal (LPC) and High Potential Perennial (HPP).

Bekure (1983) was perhaps the first person who explored crop structure in the peasant sector in a more systematic way using Weaver's Crop Combination Index (CCI). This method determines crop combinations for each spatial unit by comparing the actual hectarage with ideal, theoretical hectarage under different crop combination assumptions. The difference between the actual and theoretical crop combinations is computed using the usual standard deviation formula. The crop combination that produces the least variance defines the crop combination for a given area and the calculation is repeated for each unit. Bekure made this calculation for all Awrajas that reported crops in 1975, and seven crop combinations, ranging from one-crop to seven-crop combination, were identified. By focusing on "a maximum of three most important crops", he finally grouped the Awrajas into eight crop-combination zones (see Table 7), with a ninth one forming an indeterminate category.

Methodology Used in this Study

Traditionally, crop combinations are studied using Weaver's Crop Combination Index. Weaver's method was later modified by Thomas (1963) who included all crops considered in the computation of the index as opposed to Weaver who restricted his calculations only to the number of crops considered in each step. Coppock (1964) applied Thomas' modified version to crop, livestock and enterprise combinations.

Weaver's index determines crop combinations for each spatial unit independent of all other units, and it does not, therefore, show the extent to which crops tend to covary, i.e. locate together or mutually exclude one another. Thus, it does not identify crop structures on the basis of spatial covariance, and the crop combinations obtained may not depict the degree of association over a wider area. Moreover, the method is highly biased in favor of crops that occupy larger proportions, and it becomes less discriminating when there are many crops with low but nearly equal percentages. Due to such problems this method may produce different crop combinations for neighboring spatial units, and generalizations are often obtained either by making subjective adjustments or by focusing only on the most important crops (Coppock 1964; Bekure 1983). Thus Bekure (1983: 30-33) had to focus on the three most important crops in finally working out crop combination zones for the Awrajas, and he had to employ the location quotient to analyze the degree of concentration of individual crops. Such approaches may, however, mask important regional crop patterns.

After the pioneering work of Weaver some geographers have attempted to develop better crop combination methods. Examples include the Maximum Distance Method developed by Ayyar (1964) and the Method of Difference and Summation, and the Lower Limit Method developed by Athawale (1966). Like Weaver's index these methods also determine crop combinations for each unit independent of other units and share the problems of Weaver's index in this respect. In addition to this, the methods devised to bypass the problems of Weaver's index tend to give unduly weight to lower ranking crops and tend to produce crop patterns that conflict with real agricultural situations (Mandal 1982:260).

In this study, principal component analysis, a statistical method which identifies groups of variables whose distributions are interrelated, is used. This method extracts basic or underlying dimensions exhibited by a seemingly complex group of variables (Henshel and King 1966). In the R-mode analysis, which is used here, the original data matrix is factored to extract orthogonal components which account for as much as possible the covariance among the original 29 crops measured over 79 Awrajas. Each crop is represented as a linear combination of several components which may be written in the form:

$$Z_j = a_{j1}C_1 + a_{j2}C_2 + \ldots + a_{jn}C_n$$

where Z_j is the j^{th} observed crop; $C_1 \ldots C_n$ represent extracted components, and $a_{j1} \ldots a_{jn}$ represent component loadings. Those crops that intercorrelate most will cluster around a single component, and they provide the clue to the interpretation of the components.

The aim in principal component analysis is to determine the principal axes or components and the loadings which indicate the degree of correlation between each variable considered and the extracted components (Shaw and Wheeler 1985:276). The sum of the squared loadings for each variable on each component , which is known as communality(h^2), indicates the extent to which the components account for the total unit variance of each crop or variable, and it may be determined as follows:

$$h_j^2 = a_{j1}^2 + a_{j2}^2 + \ldots a_{jn}^2$$

The overall importance of the components extracted is indicated by the eigenvalue. The eigenvalue for each component is determined by squaring the loadings of each variable on it and summing the square loadings. When the sum is divided by the number of original variables and multiplied by 100, it gives the percentage of variance it explains (Shaw and Wheeler 1985:277).

Principal component analysis is used to analyze complex multidimensional concepts (Soja 1968). Henshel and King (1966) were among the early users; they used it in their study of crop structures of peasant agriculture in Barbados. Their study was, however, made on the basis of a crop being present or absent depending on whether it occupied at least 1% of the cropland or not. This approach has been found inappropriate in this study for two reasons. First, the use of ordinal scale puts all crops in the same category irrespective of their relative strength of land occupancy, and correlation coefficients calculated on such basis may produce spurious results. Second, crops that are found together but are weak in their absolute strength of land occupancy will be excluded and an important crop association may be lost.

In this study, the data obtained is changed into location quotient before it is subjected to principal component analysis. This approach has two advantages. First, it may reduce bias that may be introduced into the analysis due to the variable size of Awrajas. Second, it facilitates the identification of crop clusters on the basis of their relative strength of land occupancy rather than on the absolute size of cropland occupied. This method is expected to identify general patterns of crop covariance. The argument is that even though each crop may have some unique elements to its distribution, the general component or characteristic will dominate as the spatial incidence of each crop overlaps with other crops whose distribution is dictated by the same group of factors. The components identified in this way may, therefore, define the underlying structure of crops in the peasant sector. Even though crop association and crop combination are used interchangeably in the literature, crop association and crop cluster are used in this study to emphasize the fact that crop clusters are identified on the basis of their spatial covariance rather than on their concentration in a single spatial unit.

Crops Used in the Analysis

Twenty-nine crops reported in 78 Awrajas are used in this study. Data was collected from the Agricultural Sample Survey of 1983/84 made by the Ministry of Agriculture for 12 Administrative Regions for the Belg (short rainy season which starts in early spring) and Kiremt (main rainy season in which rainfall is concentrated between June and September) seasons; data was not available for Tigray and Eritrea. The crops used are given in Table 1 below.

TAble 1
Crops Used in Principal Component Analysis

No. Crop	Code	No. Crop	Code	No. Crop	Code
1. Teff	TFF	11. Chick Pea	CKP	21. Sweet Potato	SWP
2. Maize	MZE	12. Noug	NOG	22. Godere	GDR
3. Barley	BLY	13. Linseed	LSD	23. Groundnuts	GDN
4. Sorghum	SGM	14. Emmer wheat	EMT	24. Cotton	CTN
5. Wheat	WHT	15. Lentils	LTL	25. Rape seed	RPS
6. Horse beans	HBN	16. Haricot beans	HRB	26. Banana	BNA
7. Coffee	CFE	17. Vetch	VTH	27. Fenugreek	FGK
8. Enset	ENT	18. Chat	CHT	28. Gesho	GSO
9. Field pea	FDP	19. Pepper	PPR	29. Sesame	SSM
10.Millet	MLT	20. Potato	POT		

The number of crops reported varied from two in the peripheral Awrajas of Borena, Awssa and El Kere to 20 in Chebo and Guraghe.

The mode was 12, and 18 Awrajas were reported as 12-crop Awrajas. Another 12 Awrajas were reported as 13-crop Awrajas. Only 12 Awrajas reported less than 10 crops while 18 Awrajas reported more than 15 crops. Most of the Awrajas reported 10-14 crops(see Table 2 below).

Table 2
Number of Crops Reported by Awrajas.

No. of Crops	No. of Awrajas Reporting	Percent
≤ 4	4	5.1
5--9	8	10.3
10--14	48	61.5
≥ 15	18	23.1

The spatial expression of Table 2 is portrayed in Figure 1. Although the number of crops grown tends to decrease from the central highlands towards the peripheral lowlands, some transitional Awrajas like Wabe in Bale, Gara Muletta in Harrerghe, Chilga and Gonder Zuria in Gonder, and Arero in Sidamo also reported larger number of crops.

Even though some Awrajas reported as many as 20 crops, few crops stood out prominently. At the national level, teff alone accounted for 23.5% of the total cropland followed by maize, barley, sorghum, wheat and horse beans which accounted for 15.3%, 14.5% 11.9%, 9.5% and 5.9% respectively. These crops combined together accounted for 80.6% of the cropland. Another five crops, namely, coffee(2.7%), enset(2.6%), field pea(2.5%), finger millet(2.3%) and chickpeas(2.1%) together accounted for 12.2% bringing the proportion of cropland under these 11 crops to 92.8%. The remaining 7.2 % of the cropland was shared by the remaining crops.

Rank ordering of the crops showed that 17 crops held first to third place in one or more Awrajas; 7 crops ranked first, 4 crops ranked second while 6 crops ranked third. The distribution of these crops is given in Table 3 .

The number of Awrajas in which each crop is reported also showed great variation. Sorghum was reported in 75 Awrajas followed by teff, maize and barley which were reported in 72 Awrajas each. At the other extreme were crops like groundnut and sesame which were reported only in 5 Awrajas.

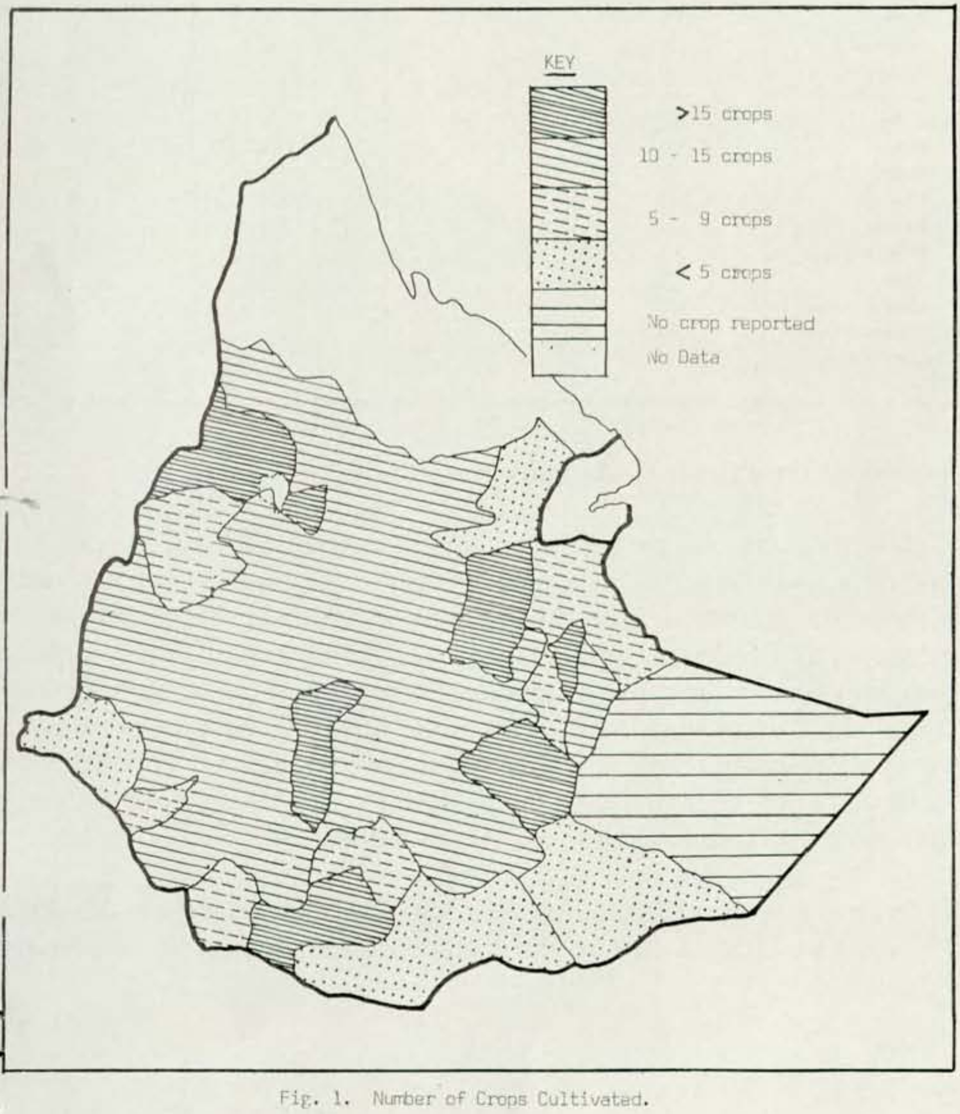

Fig. 1. Number of Crops Cultivated.

Table 3
Distribution of First, Second and Third
Ranking Crops.

Crop	No. of Awrajas Reporting	No. of Awrajas in which it ranked First	Second	Third
Teff	72	26	15	9
Maize	72	23	17	5
Barley	72	13	8	13
Sorghum	75	12	17	9
Wheat	70	1	9	12
Horse Beans	68	1	3	6
Coffee	28	2	1	6
Enset	22	-	4	2
Millet	18	-	2	2
Chat	17	-	1	2
Cotton	6	-	1	-
Field pea	65	-	-	1
Noug	36	-	-	1
Emmer wheat	32	-	-	1
Haricot beans	36	-	-	1
Groundnuts	5	-	-	2
Godere	6	-	-	1

Results of the Principal Component Analysis

Before running the principal component analysis, the 78 x 29 matrix of raw data was converted to a matrix of location quotients of the same order. The matrix of location quotient was standardized and finally subjected to principal component analysis. Varimax rotation was applied to obtain simple and more discriminatory picture of the underlying crop structures. Components with eigen- value of 1.0 or more were retained for analysis; components with eigenvalues of less than 1.0 were dropped from the study as such components " explain less of the total variance than a single variable"(Shaw and Wheeler 1985:282).

As an exploratory procedure, three separate analyses were made. First 17 crops which held first to third place in one Awraja or more were subjected to principal component analysis. This analysis yielded five components of eigenvalue of 1.0 or more. These components accounted for 62% of the total variance in the 78 x 17 data input matrix. However, the rotation employed failed to produce a simple structure and the components were difficult to interpret. In fact, some crops that were highly correlated became dissociated from one another and formed separate components.

Second, 21 crops that were reported in 10 Awrajas or more were subjected to analysis. In this procedure, 7 components with eigen- values of 1.0 or more accounting for 65.3% of the total variance in the 78 x 21 input matrix were extracted. The pattern of association in this analysis was very similar to the third analysis, which is discussed below, but it resulted in certain loss of information. Thus the loss of detail was not worth the parsimony obtained.

Third, all crops were subjected to principal component analysis. This procedure resulted in the extraction of 10 components with eigenvalue of 1.0 or more accounting for 69% of the total variance in the 78 x 29 data input. This procedure brought to surface important crop associations that were covered-up in the previous analyses due to the exclusion of certain crops in those analyses. The discussion that follows is based on this analysis.

The relative importance of these components is presented in Table 4, while Table 5, which lists the loadings, indicates the characteristics of these components. A brief description of each component follows the Tables.

Table 4.

Relative Importance of the Ten Components.

Component No.	Eigen Value	% of Total variance	% Cumulative
1	4.916	17.0	17,0
2	2.825	9.7	26.7
3	2.294	7.9	34.6
4	1.842	6.4	41.0
5	1.750	6.0	47.0
6	1.508	5.2	52.2
7	1.452	5.0	57.2
8	1.208	4.2	61.4
9	1.160	4.0	65.4
10	1.092	3.8	69.1

Crop Association Components

Principal Component I: This component, which accounted for 17% of the total variance, is expressive of the general pattern of peasant farming in Ethiopia. Six crops which together accounted for 47.3% of the eigenvalue associated with this dimension have loadings of ≥.500. The positive loading of barley and horse beans on one hand and the negative loadings of maize and sorghum on the other suggests that a move along this dimension may mean a move from the highlands to the lowlands and/or from short maturing to long maturing crops since the data used does not distinguish between cultivars. The component represents primarily highland cereal-highland pulses, and reflects the basic association underlying subsistence farming. The crops with loadings of .500 or more require a growing period of more than 120 days, a rainfall of 350-1200 mm during the growing season and temperature of 12.5-20°C. These crops are often grow at altitudes of 2200-3000 meters above sea level.

Using the component scores, the spatial expression of this component is portrayed in Figure 2 . Ten Awrajas had component scores of ≥ + 1.0.

Table 5.
The component Loadings of the Rotated Matrix.

	Principal Components										
Crops	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	h^2
EMT	.677	-.161	-.106	-.062	-.113	-.031	.022	.033	-.131	-.194	.569
EGK	.658	.175	-.152	-.013	.029	.039	-.059	-.066	.011	-.088	.505
BLY	.652	-.052	.142	-.079	-.207	-.119	.419	.259	-.083	-.096	.772
FDP	.631	.269	.073	.194	-.071	.006	-.038	-.161	.068	.069	.556
LTL	.600	.371	-.192	-.133	-.001	-.077	.257	-.185	-.027	.114	.673
WHT	.503	.159	.090	-.175	-.176	-.287	.420	-.017	-.077	.113	.626
CKP	.225	.786	.059	.079	-.146	.138	-.144	.075	-.050	-.041	.749
VTH	.003	.780	.112	-.036	-.075	-.103	.158	-.018	.048	-.157	.691
HBN	.343	.585	.078	-.187	.003	-.144	.340	-.182	-.002	.067	.674
NOG	-.183	.029	.756	.007	-.118	.274	.082	-.145	-.118	-.155	.760
TEF	-.113	.426	.698	-.104	-.091	.109	-.114	-.148	-.157	.009	.772
RPS	-.149	-.044	.615	.039	-.096	-.170	.294	-.074	-.100	-.136	.562
CHT	-.292	-.162	.517	.360	-.094	-.073	.104	-.216	-.258	-.211	.692
SGM	-.419	-.092	.582	.109	-.092	.130	-.102	-.404	-.338	-.094	.857
GDN	-.044	-.125	-.179	.785	-.018	-.052	.003	-.138	-.047	-.029	.691
SWP	-.019	-.109	.029	.717	.187	-.083	.026	.053	.109	.409	.752
PPR	-.017	.376	.081	.634	-.124	.089	-.282	.078	-.031	-.103	.672
BNA	-.126	-.096	-.150	.204	.800	-.043	.062	.027	-.038	-.014	.737
CFE	-.136	-.107	-.047	-.088	.747	-.064	-.144	.379	-.023	.029	.767
GDR	-.006	-.035	.018	-.079	.708	.031	-.057	-.076	.006	-.056	.522
SSM	.091	-.031	-.098	-.072	-.042	.801	.222	.022	.073	.187	.757
MLT	.001	.003	.269	-.001	.013	.770	-.152	-.068	-.035	-.105	.705
LSD	.188	.086	.069	-.100	-.056	.083	.756	-.181	.040	.045	.643
POT	.266	.053	.111	.283	-.010	.236	.428	.075	.060	-.205	.456
ENT	-.100	-.104	.070	-.052	.187	-.141	.081	.813	-.020	.083	.758
GSO	-.079	.087	-.126	.010	-.113	.482	.163	.632	-.030	-.053	.704
CTN	-.060	-.001	-.091	-.001	-.064	.062	.073	.065	.889	.069	.822
MZE	-.362	-.488	.149	.032	.011	.156	-.359	.061	.516	.063	.820
HRB	.161	-.144	-.123	.070	-.096	.054	.003	.052	-.068	.831	.777

A brief description of each component is given in the text.

These Awrajas had location quotients of 2.0 and above for barley, wheat and emmer wheat. All these Awrajas are found in the Central Plateau and the Arssi-Bale Highlands where a large proportion of the land is above 2000 meters and extends to over 3000 meters in many places. Annual rainfall here is 600-1400 mm/year, and due to high altitude temperatures are less than 20°C. Through out the region, the growing season is more than 120 days(see Figures 3 and 4).

Principal Component II: This component has a more specific character as it represents a purely pulse dimension; it represents a highland pulse sub-structure. Three pulse crops accounting for 55.5% of the eigenvalue associated with this dimension have high positive loading. It brings to light important variation in the spatial concentration of the highland crops. Moreover, the fact that crops that load high on Component I also load high on Component II compared to other crops and vice versa tends to suggest that Component II may be subsumed by Component I.

The map for component scores shows that these crops are highly concentrated in the North Central Massifs and northern parts of the Shewan Plateau, and form a contiguous area which is composed of N. Shewa, W.Wello, E.Gojjam, and S.Gonder. 17 Awrajas had component scores of greater than + 1.0. Most of these Awrajas had location quotients of 2 and above for chickpeas and horse beans while those with negative scores had location quotients of less than 1.0 for the same crops.

Horse beans requires temperatures of 12.5--17.50°C and grows best between 2200--3000 meters above sea level while the optimal altitude for chickpeas and vetch, whose temperature requirements are 17.5--20.0°C,lie between 1700 and 2400 meters above sea level. Excepting vetch whose optimum rainfall requirement is 400--1000 mm during the growing season, both chickpeas and horse beans require 600--900 mm during the growing period. The area in which these crops are concentrated is above 2000 metersabove sea level and receives rainfall of 1000 mm/year or more. However, it is interesting to note that even though the South

Western Highlands are also suitable to the cultivation of these crops, they do not appear to be widely cultivated there, and perhaps reflect cultural differences rather than differences in critical environmental conditions.

Principal Component III: This component is positively indexed by teff, noug and rape seed, but negatively indexed by chat and sorghum both of which are concentrated in the Harrerghe Plateau. These two groups of crops appear to mutually exclude one another. The three crops with positive loadings have similar environmental requirements. Their optimum temperature and altitude lie between 15 and 20°C and 1500 and 2400 meters above sea level respectively. Noug and rape seed require 600--1000 mm of rain while teff requires 400--600 mm of rain during the growing period; all of them need a growing period of 90 days or more. On the other hand, sorghum grows best between 1000 and 1600 meters above sea level with rainfall of 600--800 mm during the growing period.

The association between teff and noug has also been noted by others. Westphal (1975), for instance, has observed that these two crops are the leading crops in W. Shewa, E. Wellega and Gojjam.

Nine Awrajas with scores of +1.0 and above form a nucleus for this crop association, and the intensity of cultivation of these crops decreases from here in all directions. Most of the Awrajas with positive scores had teff as their first ranking crop with location quotients of 1.5 and over, whereas Awrajas with scores of -1.0 or less had location quotients of 0.5 or less for teff, but 3 and above for sorghum. The area of concentration for these crops receives rainfall of 1000 mm/year, a growing period of more than 120 days and altitude of 1500--2500 meters above sea level.

Principal Component IV : This component is indexed by ground- nuts, sweet potato and pepper whose collective loadings account for 83.3% of the eigenvalue associated with it.

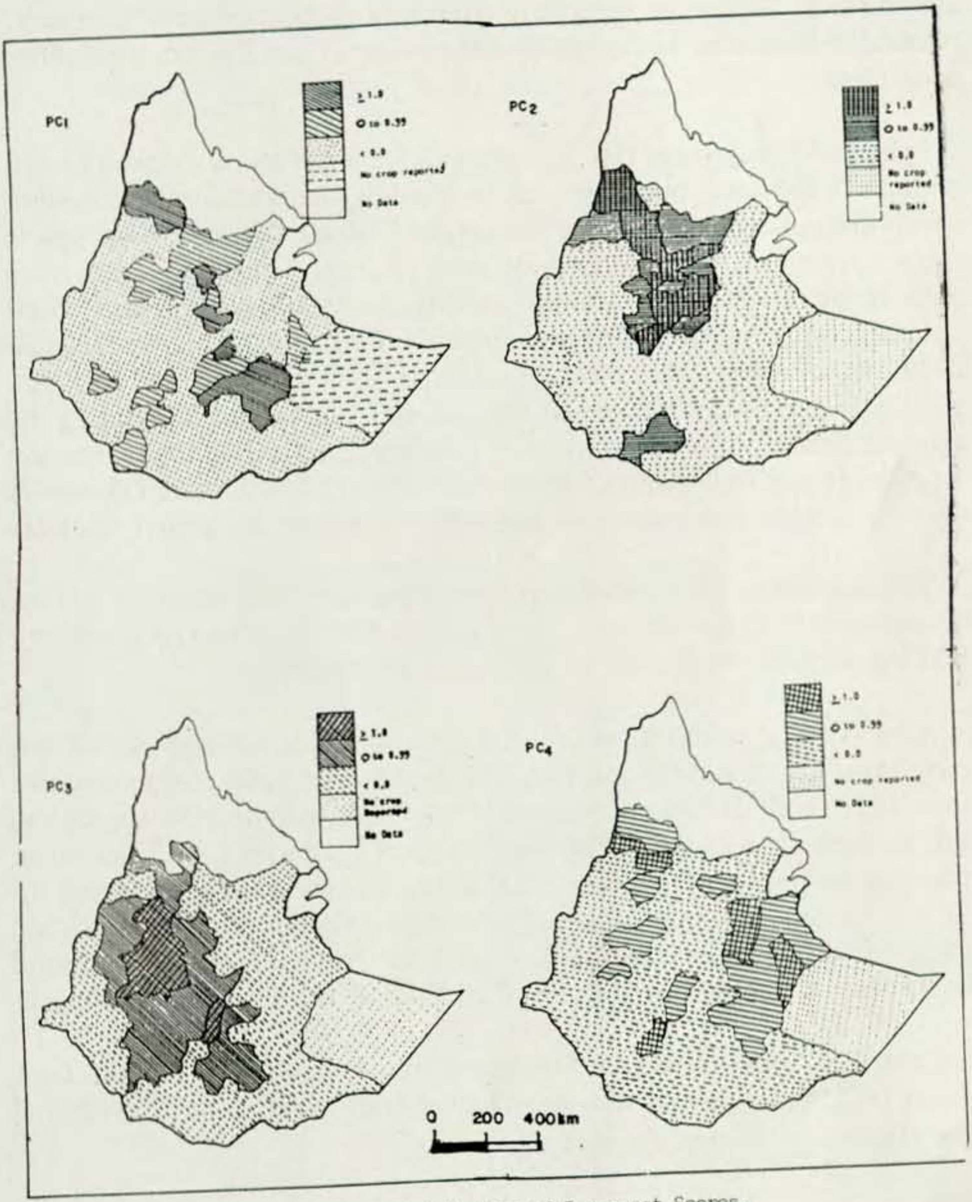

Fig. 2. Spatial Distribution of Component Scores.

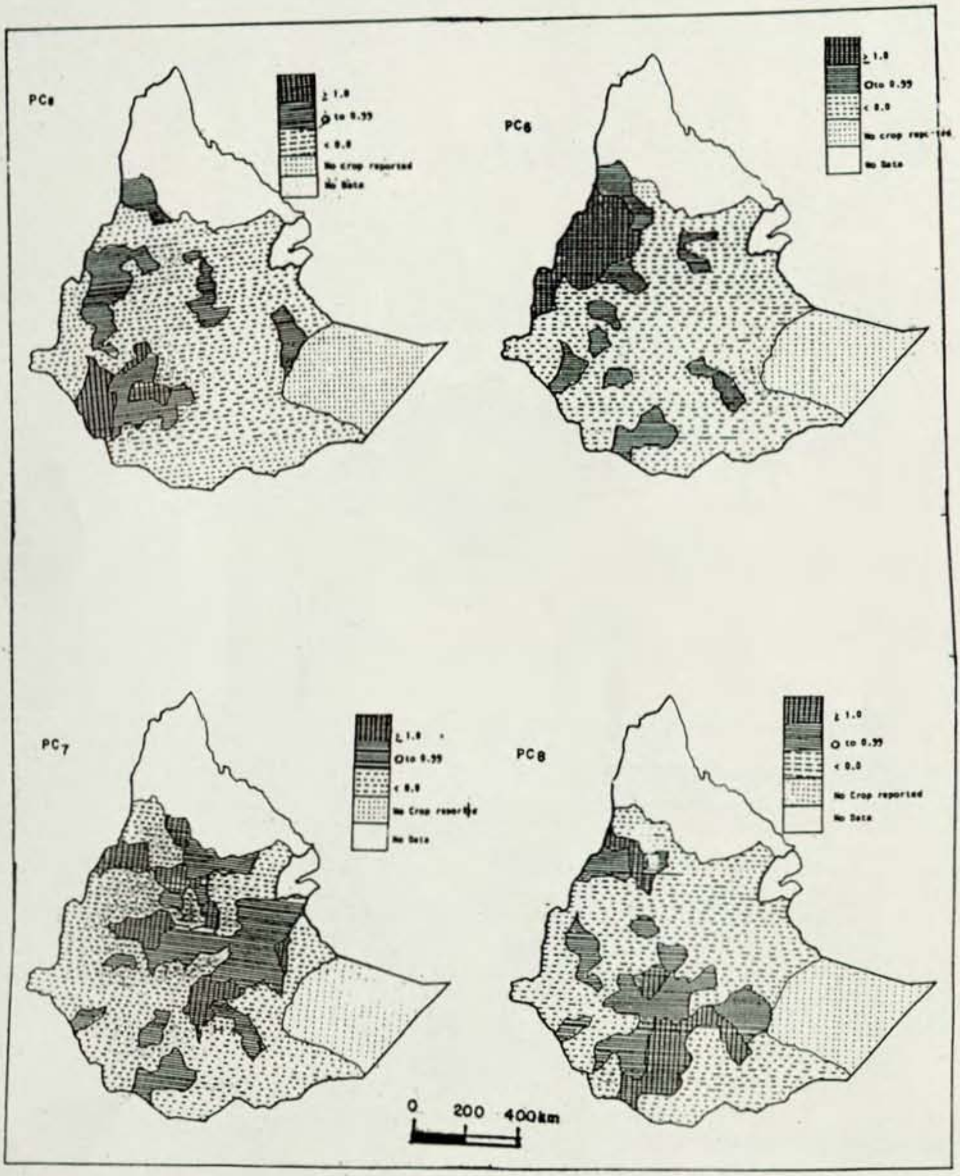

Fig. 2. (Continued).

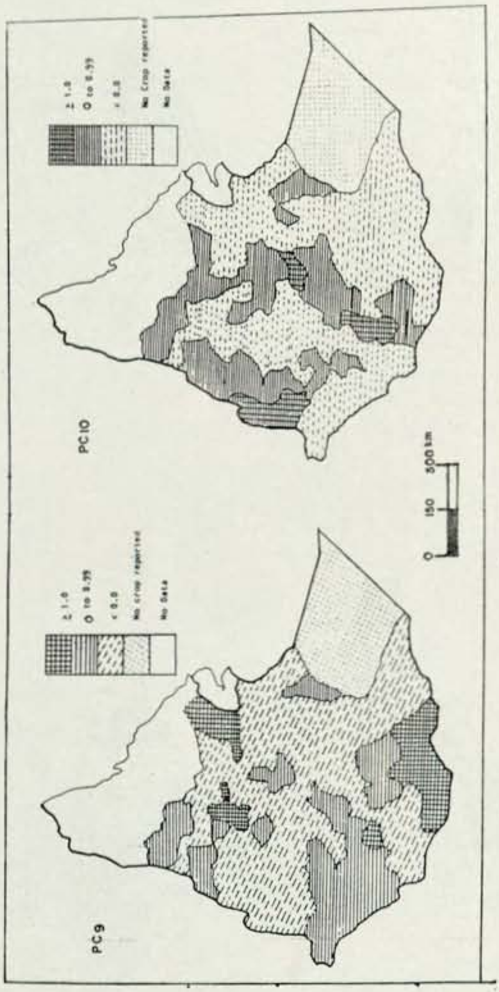

Fig. 2 (Continued)

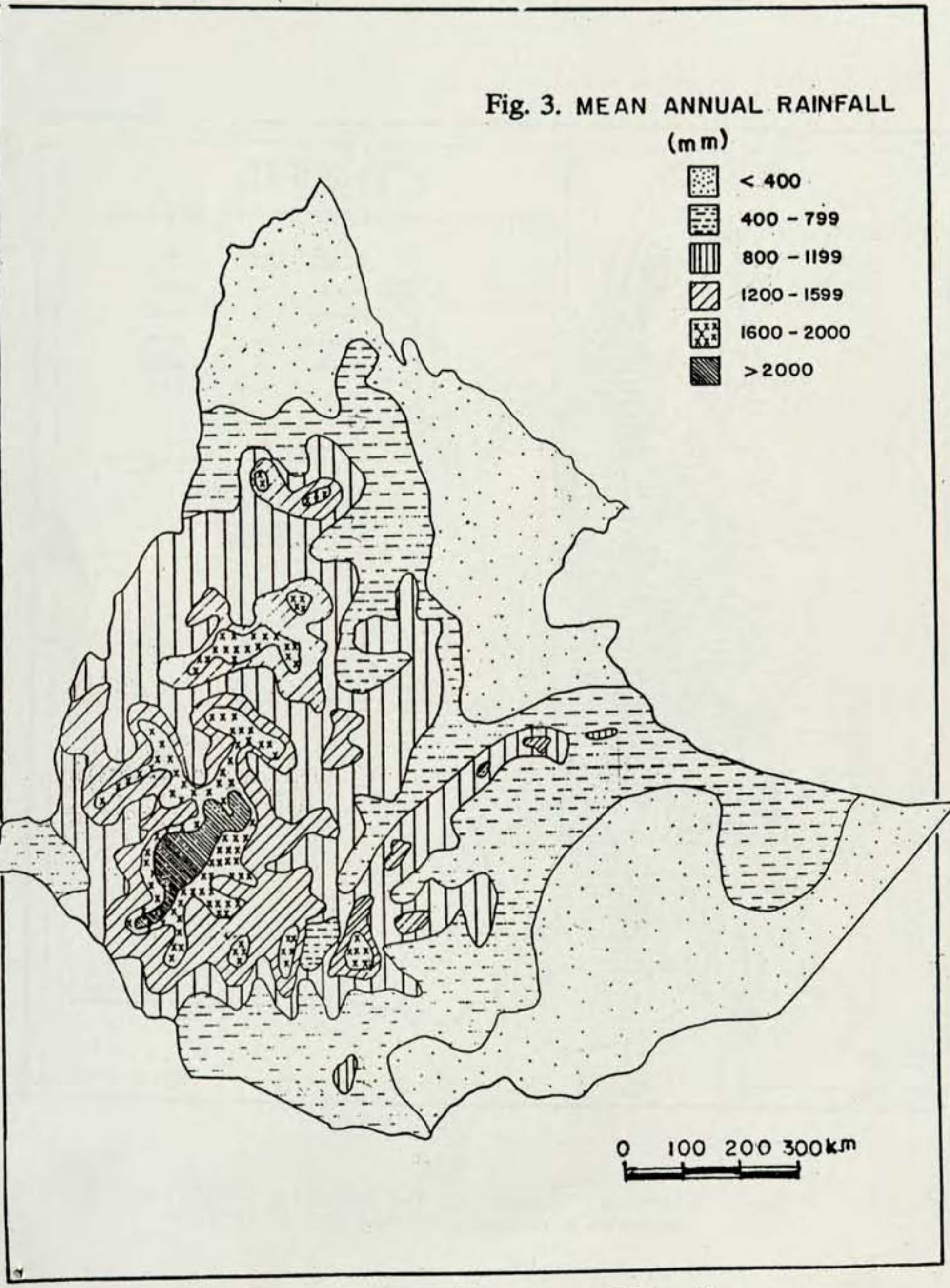

Fig. 3. MEAN ANNUAL RAINFALL

Adapted from Ethiopian Mapping Agency (1988:12)

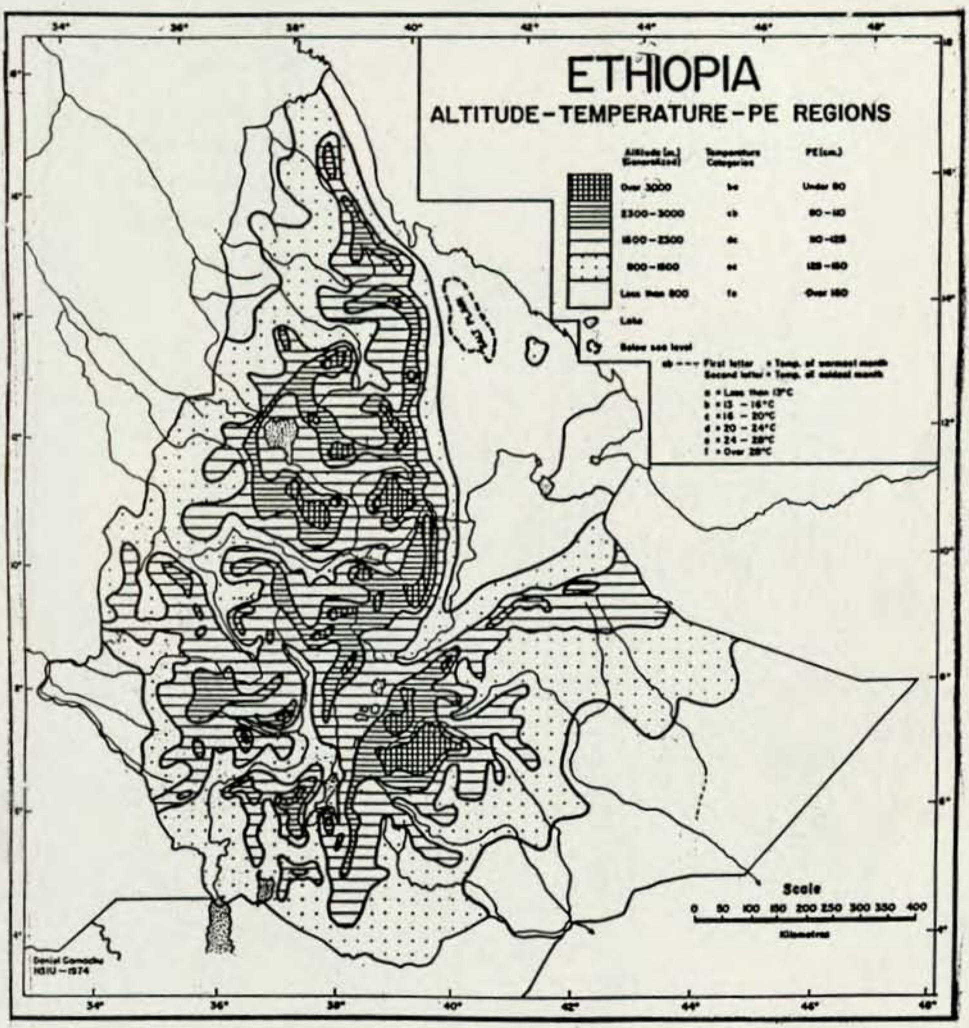

Fig.4. Altitude, Temperature and Potential Evapotraspiration Patterns in Ethiopia (After Daniel,1972:25).

Although 7 Awrajas had component scores of > + 1.0, the distribution is haphazard with slight concentration in the Harrerghe and Bale Plateaux. These crops grow well between sea level and 2000 meters above sea level but may extend up to 2400 meters under favorable conditions. They require temperatures of 22.5--27.5°C and rainfall of 500--1000 mm during the growing season.

The haphazard distribution makes it difficult to compare the spatial patterns exhibited by this component with environmental conditions. However, the concentration of these crops in the Harerghe Highlands has also been noted by Westphal (1975). Awrajas located in this zone accounted for almost all of the cropland under groundnut while four Awrajas, two of which are in Gonder Administrative Region and the rest in Harerghe, accounted for 38.4% of the cropland under pepper

Principal Component V: This dimension is indexed by coffee, banana and godere(a root crop), and together cover 97% of the eigenvalue associated with it. An examination of the environmental requirements of these crops shows that banana requires temperatures of 20--25°C and grows best between sea level and 1600 meters above sea level while coffee, which requires temperatures of 20-22°C, can grow between 1100 and 2200 meters above sea level, but performs best between 1500 and 1800 meters. Both crops need rainfall of 1200-1600 mm during the growing season.The environmental requirements of godere are not available.

The distribution of the component scores shows that most of the Awrajas with scores of > + 1.0 are concentrated in the south western parts of the country where rainfall is more than 1400 mm/year. However, the positive scores for the central and north eastern Awrajas is puzzling.

Principal Component VI: This component represents finger millet-sesame dimension; both crops account for 82% of the eigenvalue associated with it. Sesame needs temperatures of 25--27°C and grows best between sea level and 1200 meters, but can grow up to 1600 meters while finger millet, with optimum temperature requirements of 20--25°C, grows between 500 and 2200 meters with the optimum altitude lying between 1000 and 1800 meters. The length of growing season for these crops should not be less than 120 days during which period rainfall received should be 500--900 mm.

The spatial expression of this component shows that these crops are highly concentrated in the north western parts of the country. Awrajas with scores of > + 1.0 are concentrated in areas where the general elevation is less than 2000 meters, and rainfall is 600--1000 mm/year. All Awrajas with scores of > + 1.0 had location quotient of ≥3.0 for both crops.

Principal Component VII: This component represents the potato-linseed dimension. These two crops have almost identical environmental requirements. Both of them can grow between 1800 and 3200 meters above sea level, but perform best between 2300 and 2800 meters, and require 600--800 mm of rain during the growing season which should be 150--180 days long. Optimum temperature for both crops is 12.5--17.5°C.

There is not a distinct area of concentration for this dimension. Positive scores for it are widely distributed in the Arssi-Bale Highlands, Harerghe Highlands, Shewan Plateau and North-Central Highlands.

Principal Component VIII: This dimension represents the enset-ghesho association. Both crops load high on it accounting for 89% of the eigenvalue associated with it. The map for component scores of this dimension indicates a major core in the south-central parts, and a minor core in the north-western parts of the country.

The north-western core is primarily due to high cultivation of ghesho in Gonder Administrative Region. Four Awrajas here-- Chilga, Debre Tabor, Gonder Zuria and Libo-- accounted for 45.7 % of the cropland under this crop, while Arero Awraja in Sidamo Administrative Region accounted for 45.4% of cropland under ghesho bringing the total cropland under ghesho in these five Awrajas to 96.1%. The major core in the south-central part is mainly due to enset which is the staple food for many ethnic groups that occupy parts of the Rift Valley, the south western highlands of Shewa and the eastern highlands of Sidamo. Many Awrajas here have enset as their second or third ranking crop.

Since environmental requirements of ghesho are not available, it is not possible to evaluate its spatial distribution. Enset requires temperatures of 15--20°C and rainfall of 1100-1500 mm during the growing season; it grows best at altitudes of 2000--2500 meters. The major core coincides with areas where the general elevation is above 2000 meters, and gets rainfall of 1000 mm or more. The extreme south of this core, however, appears to be only marginally suitable to this crop.

Principal Component IX: This component represents the cotton-maize association, both of which cover 91% of eigenvalue associated with it. Only five Awrajas had scores of $\geq +1.0$ two of which are two-crop, peripheral Awrajas with maize covering more than 85% of the total cropland in each Awraja.

Both crops have similar environmental requirements; they need temperatures of 20-27°C and rainfall of 600--900 mm during the growing season which should not be less than 120 days. Although they can grow between sea level and 1800 meters, they grow best at altitudes of 500--1300 meters.

Principal Component X: This is a haricot bean dimension whose single loading account for 63% of the eigenvalue associated with it. The positive component scores for this dimension form two semi-parallel zones in a north-south direction. One zone extends along the Ethio-Sudan border and the other extends across the middle of the country.

Haricot bean was reported in 36 Awrajas out of which 13 had location quotients of $\geq$2.0.

Haricot bean requires temperatures of 20--23°C and growing season of 90--120 days during which time rainfall should be 500--1000 mm. Thus it can grow at altitudes of 1000--2100 meters with the optimum zone lying 1400--1800 meters. Most of the Awrajas with scores of $\geq$ + 1.0 are found in areas where elevations are $\leq$ 2000 meters and rainfall is 500--1200 mm/year.

Comparison of the Results

As discussed in the previous sections, some of the studies made earlier have identified crop combinations on the basis of various criteria. The crop combinations identified by FAO/UNDP (1984:13), Bekure (1983) and the Hunting Technical Service (1976) are presented in Tables 6,7 and 8, and comparison is made between these crop groupings and the crop clusters identified in this study.

A comparison of the crop clusters identified in this study with the 20 crop combinations identified by FAO/UNDP experts shows that the two methods have produced different crop groupings. The only resemblance is for crop clusters of the first and second components which are similar to FAO/UNDP's first and nineteenth crop combinations respectively to some extent.

Table 6
Crop Combinations By FAO

1. Food barley Oat Horse potato	2. Bread wheat Wheat, durum sugar beet	3. Teff	4. Enset
5. Highland sorghum Highland maize Grape	6. Coffee	7. Banana	8. Lowland sorghum Lowland Maize Lima bean
9. Finger Millet	10. Ground nuts Sesame	11. Cotton	12. Paddy rice
13. Sugar cane	14. Malting barley Rape seed	15. Pyrethrum	16. Tea
17. Soya bean Cow pea Chillie pepper Kenaf	18. Tobacco	19. Chick pea Lentil Field pea Grass pea (vetch)	20. Niger Seed Safflower Sunflower

The underlined crops ar ethe rpresentative crops for each crop combination.

Source: FAO/UNDP (1984), p. 13.

Table 7
Crop Combinations by Bekure

1. Maize, Sourghum	5. Teff, sourghum, maize
2. Teff, maize, enset	6. Teff, barley, wheat
3. Teff, sorghum, African millet	7. Sorghum, teff
	8. Wehat, barley, horse beans

Source: Bekure (1983:30)

Table 8

Altitude-based Grouping of Crops by Hunting Technical Service

Altitude (meters)	Crop Group
< 1500	Maize, sorghum, teff, haricot beans
1500-2000	All cereals, lentils, haricot beans, chickpeas
2000-2500	Finger (African) millet, wheat, barley, teff, all pulse crops, linseed, noug, safflower
2500-3000	Teff, wheat, barley, beans, peas, lentils, vetch
>3000	Teff, barley

Source: Hunting Technical Service (1976:24)

The rest of the associations show different patterns. For instance, coffee and banana, which form two separate combinations according to FAO/UNDP form one cluster in this study, but an examination of their environmental requirements indicates that the two crops have a very wide zone of overlap. Similarly, teff and noug (nigger seed) belong to different clusters according to FAO/UNDP but form one cluster in this study; similar pattern is observed for maize and cotton. Conversely, sesame and groundnut form one group according to FAO/UNDP, but belong to different groups in this study.

It is true that FAO/UNDP experts based their crop combinations purely on environmental requirements, irrespective of the relative occupance of crops while this study is based on actual crops cultivated by peasants. However, the crop clusters identified in this study have also similar temperature and rainfall requirements reflecting the general tendency among peasants to grow those crops which are suitable to their local conditions.

A comparison with Bekure's crop combinations revealed that only crop combination 8 is similar to Component I. In some cases, crops that formed one combination in Bekure appeared to mutually exclude one another in this study. For instance, whereas teff, sorghum and maize formed one combination in Bekure's study, sorghum and maize loaded negatively on Component III which is a teff-noug-rapeseed cluster in this study. A comparison of component scores at Awraja levels showed similar discrepancy even for those Awrajas that scored high on more than one Component. Awrajas like Chilga, which scored high on Component VI (millet-sesame cluster) and Component VII (linseed-potato), for example, scored poorly on Component III even though teff, finger millet and sorghum formed its dominant crop combination in Bekure's study.

The crop groupings presented by the Hunting Technical Service (1976:24) represent "groups of suitable crops on the basis of altitude", and may not be strictly treated as crop combinations. Excepting for group 4 which is somewhat similar to Components I and II, all others are dissimilar and the crop groups designated here even conflict with other studies. FAO(1986:23), for instance, stated that above 2500 meters "maize, sorghum, millet, teff and chickpeas are almost wholly absent", but in the grouping presented by Hunting, teff is presented as one of the principal suitable crops growing even above 3000 meters. Similar problems exist for the 1500-2000 meters where all cereals are taken as suitable for this zone.

CONCLUSION

The method employed in this study shows that the 10 components extracted summarize over two-thirds of the variation in the cropping patterns of Awrajas in Ethiopia while about one-third remains unaccounted for despite the inclusion of 29 crops in the study. This suggests that the actual cropping patterns may have been dictated by other factors too, especially socio-cultural and/or demographic factors. The method employed in this study focused on relationships between the crops considered only, and further study is required to gain a fuller understanding of the influence of other factors on cropping patterns. Food preference could be an important factor which may have distorted cropping patterns. According to FAO (1986: 121), cereal preference followed the order teff, barley, sorghum and wheat. Soils, although more amenable to change than climatic factors, may also have influenced cropping patterns especially when fertilizer availability and soil management knowledge are limited.

Even though the method used here produced distinct crop associations, it did not totally overcome the problem of mapping faced in crop-combination studies as certain Awrajas scored high on more than one component. Examples include Gonder Zuria which scored high on Components II, IV and VIII; Libo on Components II and IV; Debre Tabor on Components II, VI, VII and VIII; Gayint on components II and IX; Agew Midir components III and VI, and Assossa on Components VI and X. This could be due to internal variations in physical conditions of such Awrajas. It looks crop combination studies will have to be done on smaller units, preferably at Woreda or lower levels for results to be more reliable and useful. It also points that much work has to be done to improve the existing methods and/or develop better methods of crop combinations in order to overcome the problems encountered in such studies.

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