Evaluation of Crop Management Effects on Fiber Micronaire, 2000-2002

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Abstract

Arizona has experienced a trend toward increasing fiber micronaire values in recent years resulting in substantial discounts on fiber value. There is some evidence to suggest management can influence fiber micronaire. Approximately 560 cases were identified in cotton production areas in Arizona ranging from the lower Colorado River Valley to near 2,000 ft. elevation with grower cooperators in the 2000-2002 seasons. Field records were developed for each field by use of the University of Arizona Cotton Monitoring System (UA-CMS) for information such as variety, planting date, fertility management, irrigation schedules, irrigation termination, defoliation, etc. Routine plant measurements were conducted to monitor crop growth and development and to identify fruiting patterns and retention through the season. As the crop approached cutout and the lower bolls began to open, open boll samples were then collected from the lowest four, first position bolls (theoretically the bolls with the highest micronaire potential on the plant) from 10 plants, ginned, and the fiber was then analyzed for micronaire (low 4). From that point forward, total boll counts per unit area and percent open boll measurements were made on 14-day intervals until the crop was defoliated. Following defoliation, final plant maps were performed. Relationships among low 4 sample micronaire, irrigation termination (IT), defoliation, and final crop micronaire were analyzed. Results indicate strong relationships with final fiber micronaire for factors such as total heat units (HU) accumulated by the crop from planting to IT, variety, region of production (environment), and green boll load at cutout. Results showed that as total HU accumulated from planting to IT exceeded 2945 that micronaire levels increase significantly, especially for some districts (Paloma and Maricopa) and producers.

Introduction

In recent years, an increasing percentage of the Arizona cotton crop has been classified with micronaire ranges in excess of 4.9, resulting in a discount of the market value of the fiber. In 1999, slightly over 40% of the Arizona Upland cotton crop was classed with micronaire values greater than 4.9. For example, Group 6 micronaire values (5.0-5.2) can result in \$0.05/lb. discounts and Group 7 ($\geq$5.3) \$0.10/lb. discounts. With low market values of cotton lint, as have been experienced recently (i.e. ~ \$0.50/lb.), discounts of this magnitude can have a devastating impact on farm revenues. Some economists have estimated that this problem has resulted in a loss of revenue to the Arizona cotton producers of approximately \$13 to 15 million per year in the past several years. However, some cotton marketing professionals in Arizona have indicated that they believe these losses in revenue due to high micronaire are in the range of \$20 to 25 million per year over the past five to six years. Thus, this problem is seriously affecting the profitability of Arizona cotton production at this time.

Fiber properties such as micronaire are the product of three primary factors: 1) genetics, 2) environment, and 3) management. The statement is often made that "only 30% of the cotton micronaire properties are determined by genetics (variety) with 70% determined by agronomic management [sic]". This claim is hard to substantiate.

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The trends associated with increasing micronaire levels in Arizona reveal a slight increase in average micronaire values in the early 1990's (~1993) and again in about 1996. It is interesting to note a similar trend is apparent with data from the entire U.S. cotton belt. In addition, in review of the micronaire distributions among all cotton producing regions in the U.S., there is a somewhat normal distribution pattern with a peak micronaire value at approximately 4.9-5.0 and a distinct drop in proportions of the crop with fiber above 5.0. These two points support the hypothesis that there is a strong genetic component associated with recent trends in Arizona and U.S. micronaire values and that varieties have been developed to "push" the micronaire limits (i.e. 5.0). There is also ample evidence to support the position that Arizona, particularly the low elevation locations (< 2,000 ft.), has a hot and sunny environment that is conducive to high micronaire production (hot conditions for both day and night temperatures). Thus, it appears that in Arizona, we are producing a cotton crop in an environment conducive to high micronaire production. This is compounded as a whole by varieties that have a tendency toward high micronaire as well. The relationships associated with high micronaire and the third primary component (management) is not well understood in the context of desert cotton production.

Based on an analysis of data from several locations in Arizona, it appears that there is indeed a relationship associated with location and variety and fiber micronaire (Silvertooth, 2001). From this data, there also appears to be a relationship between fiber micronaire and management, in that certain growers within given areas tend to have a very high percentage of their crop classed with high micronaire and another set of growers in the same area have a very low percentage of their crop with low micronaire using basically the same group of varieties. It is the purpose of this research project to better delineate the contributions associated with genetics, environment, and management on fiber micronaire. More specifically, this project will attempt to focus on management factors that are important in determining fiber micronaire. The ultimate objective is to identify management factors that are critical in producing both high yields and micronaire values < 5.0. Results from the 2000 and 2001 season were summarized in earlier articles (Silvertooth et al., 2001; Silvertooth et al., 2002). Companion studies have also been conducted to focus on an evaluation of irrigation termination and variety (genetics) interactions at the University of Arizona Maricopa (MAC) and Yuma Valley (YVAC) Agricultural Centers (Silvertooth et al., 2001; and Silvertooth and Galadima, 2002).

Methods and Materials

Approximately 250 cases (fields) in 2000, 150 in 2001, and 160 in 2002 were identified with grower-cooperators throughout central and western Arizona with Upland (*Gossypium hirsutum* L.) cotton. Routine plant measurements for each site were carried out on a regular basis at approximately 14-day intervals throughout the season. Measurements taken included: plant height, number of mainstem nodes, number of flowers per 50 feet of row, and the number of nodes from the top fresh white flower to the terminal (NAWF). Sequential plant maps were also collected on regular intervals. Petiole and leaf blade samples were also be collected at the time of plant measurements for nutrient analyses in the laboratory. As the crop approached cutout and the lower bolls began to open, open boll samples were collected from the lowest four, first position bolls (theoretically the bolls with the highest micronaire potential on the plant) from 10 plants, ginned, and the fiber analyzed for micronaire (low 4). From that point forward, total boll counts per unit area and percent open boll measurements were made on 14-day intervals until the crop was defoliated. Relationships among low 4 samples (micronaire), irrigation termination (IT), defoliation, and final crop micronaire are evaluated below. Field records were developed for each field by use of the University of Arizona Cotton Monitoring System (UA-CMS) for points such as variety, planting date, fertility management, irrigation schedules, irrigation termination, defoliation, and all plant measurement data.

The aggregate dataset that was developed from 560 cases monitored over the course of the 2000, 2001, and 2002 seasons was subjected to the following analyses: correlation, principle component analysis, and a series of regression analyses. Locations for the cases monitored during the 2000, 2001, and 2002 seasons are presented in Tables 1-3. Results were analyzed statistically (correlation, principal component (PC), and regression) in accordance to procedures outlined by Steel and Torrie (1980) and the SAS Institute (SAS, 1990).

Classification and Regression Trees (CART), a computationally intensive statistical algorithm was used to determine the importance of how a host of factors ranging from variety, Heat Units Accumulated after Planting (HUAP), farm, district, boll load, top 4 micronaire, low 4 micronaire, and other factors influence micronaire. Codes for all varieties as used in the analysis are shown in Table 4a and 4b. Final micronaire readings of each trial are the dependent variable being measured in this analysis. To understand the algorithm, think of a jar full of marbles with each micronaire reading from a trial representing one marble in the jar. Each marble or micronaire trial has farm, district, variety, etc. stamped on it. The first question CART addresses is what variable and accompanying magnitude can be used to split the marbles into two jars so that the micronaire readings in each jar are as close to one another as possible. Closeness if defined in relation to total sum of squared errors for this analysis. Then, subsequent divisions occur until all price quotes are placed into terminal categories or nodes of the same value or less than a minimum number of observations (5 for our analysis). Although a variable may not give the best split for a node, it may give the second or third best split. CART utilizes this concept of surrogate splits to determine the relative importance of different variables. A surrogate split is essentially how well each variable predicts the action of the best linear split. In addition, missing data for independent variables are filled in with predicted values based on correlations of existing data. CART keeps track of the performance of each variable for all splits and normalizes all variables so that the most important variable has a ranking of 100. This information is provided in Table 4c.

A tree with one node for every observation would have no node impurity but would likely produce spurious results from a test sample. Whereas, a very small sized tree will inadequately represent the relationships embodied in the data. To determine the trade-off between tree complexity and accuracy, optimal tree size was determined using the *v*-fold (*v* equal to 10 for our results) Cross-Validation (CV) procedure. This is a preferred method for sample sizes less than around 900 cases (Stone). The CV procedure has been referred to as the “leave-one-out” estimate. First, the entire data is randomly divided into v different subsets, $L_1, \ldots, L_v$, that are equal or nearly equal in size. A classification tree with a specified number of terminal nodes is computed V times, each time leaving out one of the L_v subsamples out to serve as a test sample. Misclassification costs for each L_v test sample are then averaged over each of the different sized trees to determine their respective CV error. The explanatory tree for our data shown in Figure 1 is the tree with the minimum CV error. Additional information regarding the procedures and properties of estimates obtained from CART are discussed in Breiman et al. (1984), Efron and Tibshirani (1991), Horowitz and Carson (1991), Lim, Loh, and Shih (1997), and Tronstad (1995).

An additional evaluation was conducted using PC analysis to basically determine which variables belong to the same physiological grouping that could be linked to the final micronaire. By using PC analysis unrelated variables are separated into their related groups called PCs so that variables with strong association in the same group can be scored along independent axis against the dependent variable in a subsequent reduced regression procedure. The restructured groups contain the many correlated variables in smaller sets of components of the original variables herein called PC1,...,PCn (Table 5). Principal components (PC1,…,PCn) are typically considered meaningful if they possess an eigenvalue >1 and if the percentage of total variation explained by the PCn is high. The variable that contributes least to the underlying relationship within the grouping of variables (PCn) can be deleted from further analysis thereby simplifying the data set. Data codes for the characteristic cotton variables measured are presented in Table 4a.

Results

The body of data from the 560 cases that were sampled during the 2000-2002 seasons was analyzed by use of correlation procedures, PC analysis, selective regression procedures, and CART analyses. In each case, identifying a family of factors relating to the final micronaire were the target objectives.

Principal Component Analysis and Stepwise Regression procedure

A PC analysis indicated that the first PC has an eigenvalue of 16.08 and explains 47% of the total variation in the data set (Table 5). This eigenvalue is relatively large and suggests that PC1 represent several variables that should be considered for further evaluation. Principal component 2, 3, and PC4 explain an additional 16, 9, and 7% of the total variation respectively. Others account for a much smaller variation and therefore were dropped from further evaluation. By examining the eigenvectors (weights-W) and the rotated factor patterns with the PC scores (loadings-L), variables with large W and L, either negative or positive are considered to contribute to the PC. From Table 5, HNRPB, HUC0, NODESF, HUF, FFBCO, FRF, Yield, and FFBF had high loadings and were considered from PC1. Additional variables considered from PC 2, 3, 4, and 5 include, P/M, HNRF, FFBF, FRF, NACB, HNREB, HUPHS, HUEB, HUP-IT, HUJ-IT, R25MIC, Top4MIC, Low4MIC, and NODESF. The selected variables were then subjected to a stepwise regression procedure against the “finalmic”. Results of the summary of the stepwise selection procedure indicate that Low4MIC, Top4MIC, HNRPHS, HUP-IT, P/M (GB/M), YIELD, FRPHS, and FREB are parameters that have significant influence in determining the value of the final micronaire.

From the analyses that have been conducted (basic correlation analysis and a series of multiple regression models), a few parameters have shown some significance. These parameters include:

1. Heat units accumulated after planting to irrigation termination (HUAP-IT).
    a. In general, final micronaire increased with HUAP.
2. The number of green bolls on the plant as the crop approached cutout.
    a. As the number of green bolls increased, the micronaire tended to be lower
3. The position of the first fruiting branch.
    a. With lower first fruiting branch, micronaire tended to be lower.

From a physiological point of view, the relationships associated with these parameters make some sense. Point 1 is consistent with the results from the IT X Variety experiments at MAC and YVAC previously described. Point 2 is logically related to lower micronaire due to a larger carbohydrate sink being associated with a larger green boll load and thus more competition for existing carbohydrates among existing bolls (and fibers). With the generally uniform fruiting patterns experienced in the 2000, 2001, and 2002 seasons, Point 3 seems reasonable in that boll filling periods for all stages of the fruiting cycle would be similar. This would result in more uniform micronaire development and less tendency for a high carbohydrate deposition rate to occur that might be reflected in higher micronaire readings. However, it is reasonable that if a non-uniform fruiting pattern were experienced (gaps occurring in the fruiting pattern of the crop) that a lower first fruiting branch may result in higher micronaire since the existing bolls on the plant would have less carbohydrate competition and therefore possibly a longer boll filling period. This is speculative however, and points out the need for a continuation of work like this for additional seasons.

CART Analysis

Figure 1 provides a tree diagram of the variables and their levels or classes that CART selected as being most important for explaining the final micronaire reading from each trial. For example, trials with a variety of; AP6101, AP7126, AP9257, BR303, BR9801, BXN49B, BT20, DP20B, DP90B, DP388, DP422BR, DP448B, DP488, DP555BR, DP565, DP655BR, DP675, DP5415, FM658, FM966, FM958, FM989BR, HS46, JSX22, OPAL, PM1218BR, PM1560, PM1560BR, SG96, SG821, STV420, or STV580; heat units accumulated since planting (HUP-IT) less than or equal to 2,996.5; and farmer 1-27, 30-32, 34, 36-69, 41, 44-48, or 50 resulted in cotton lint that was classed together with a micronaire reading of 4.398. Most trials were pushing the discount range of 5.0 or greater for micronaire when HUP-IT exceeded 2,944.5 at irrigation termination for the districts of 6 and 10 or Paloma and Maricopa.

The relative importance of variables determined by CART is described in Table 3. Micronaire readings of the Top 4 bolls came out as being the most important factor (100.00) followed closely by the low 4 micronaire readings (94.74), and farmer (90.26). Variety (84.12), random 25 micronaire (81.51), district (66.26), and HUP-IT or heat units after planting at the irrigation termination date (62.61) also rank at the top of factors that can predict final micronaire at harvest. Note that of the four different classes considered for transgenic varieties (none, Bt, RR, and stacked), transgenic was not a significant factor for influencing micronaire with a relative importance ranking of only 1.69. Year is also relatively low at only 14.24, suggesting that heat units and other agronomic factors or signals account for most of the variation in micronaire across crop years.

Acknowledgements

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Table 1. Cotton fiber quality (micronaire) assessment locations, AZ, 2000.	
Districts	Sites
Buckeye	Moore UAVT Youngker
Casa Grande	Pate
Eloy	Dixon Shedd TOFASL
Magma	Barcello Koepnick
Maricopa	Clayton CN9 Cooley Kortsen Field 30 NMGT OBS Salmon Scott UAVT IT/VAR
Mohave	DWAK VWAK Sherrill Vandersl
Parker	CRIT-UAVT Hancock McGuire Mullion
Sacaton	Button
Stanfield	TOFAVV
Tonopah	Gill Odom Reed
Vicksburg	Cramer
Yuma	Barkley Dunn Hulstran Marlatt Osborn Weichens

Table 2. Cotton fiber quality (micronaire) assessment locations, AZ, 2001.

Districts	Sites
Buckeye	UAVT Youngker
Coolidge	Bartlett Cockrill
Eloy	Shedd Warren
Marana	NMGT
Maricopa	NMGT UAVT IT/VAR
Mohave	DWAK Vanderslice
Parker	CRIT-Rayner CRIT-Sprawl
Gila Bend – Paloma Ranch	UAVT
Safford	NMGT
Stanfield	Ollerton
Tonopah	Odom
Yuma	Dunn IT/VAR Monte Lee – UAVT Platt Woodhouse - UAVT

Table 3. Cotton fiber quality (micronaire) assessment locations, AZ, 2002.

Districts	Sites
Buckeye	UAVT
Eloy	Arizona City
Gila Bend – Paloma Ranch	UAVT
Marana	NMGT
Maricopa	NMGT IT/VAR Population UAVT FISE
Yuma	IT/VAR San Luis-UAVT Welton-UAVT

Figure 1. Tree of variables and levels or classes for explaining the micronaire level.

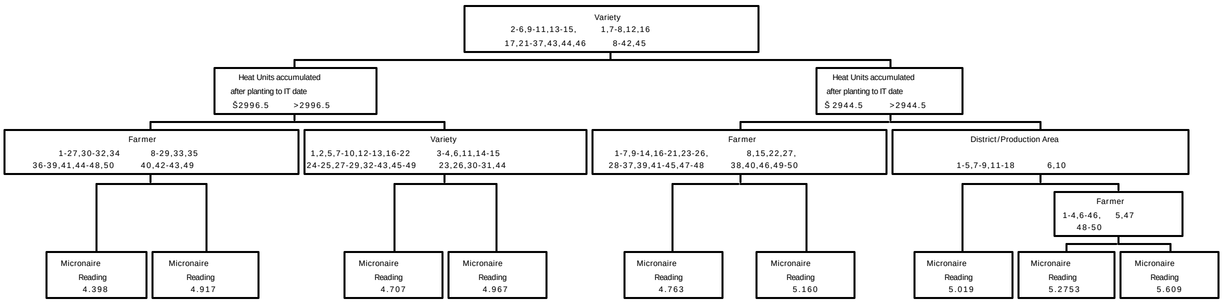

Table 4a. Code for Varieties, 2000-03			
1	AG3601	26	DP5415
2	AP6101	27	FM658
3	AP7126	28	FM966
4	AP9257	29	FM958
5	BR303	30	FM989BR
6	BR9801	31	HS46
7	BR9802	32	JSX22
8	BXN47	33	OPAL
9	BXN49B	34	PM1218BR
10	BT20	35	PM1560
11	DP20B	36	PM1560BR
12	DP33B	37	SG96
13	DP90B	38	SG105
14	DP388	39	SG125BR
15	DP422BR	40	SG215BR
16	DP428B	41	SG501BR
17	DP448B	42	SG747
18	DP449BR	43	SG821
19	DP451BR	44	STV420
20	DP458BR	45	STV474
21	DP488	46	STV580
22	DP555BR	47	STV4691B
23	DP565	48	STV4793R
24	DP655BR	49	STV4892BR
25	DP675		

Table 4b. Code for Districts, 2000-03			
1	Yuma	10	Maricopa
2	Yuma/Roll	11	Sacaton
3	Yuma/Mesa	12	Casa Grande
4	Parker	13	AZ City / Eloy
5	Mohave	14	Eloy / Sunshine
6	Paloma	15	Coolidge
7	Buckeye	16	Eloy
8	Stanfield	17	Marana
9	Tonopah	18	Safford

Table 4c. Relative importance of variables in explaining the micronaire, 2000, 2001, and 2002 crop year trials.

Variable	Relative Importance	Number of Categories
Top 4 Micronaire – T4	100.00	
Low 4 samp le micronaire – L4MIC	94.74	
Farmer / Cooperator	90.26	50
Variety	84.12	49
Random 25 micronaire sample – R25MIC	81.51	
District	66.26	18
Heat Units Accumulated since Planting (HUAP) at irrigation termination date HUP-IT	62.61	
Nodes at peak bloom – Nodes PB	42.95	
HUAP at peak bloom - HUPB	40.87	
Height to Node Ratio at peak bloom - HNRPB	40.39	
Height to Node Ratio at cut out - HNRCO	40.20	
HUAP at cut out - HUCO	37.39	
HU after January 1 before planting - HUA1J	36.89	
HUAP at boll count - HUBC	34.37	
Fruit Retention at cut out - FRCO	28.62	
Nodes at cut out - NodesCO	22.56	
HUAP at early bloom - HUEB	21.14	
Green Bolls / meter at cut-out - GBM	21.12	
Final Yield - FY	20.96	
HUAP at pin head square - HUPHS	17.49	
Heat Units Final - HUF	17.11	
Irrigation Termination HU after Jan 1 - ITHUAJ	14.75	
Year	14.24	3
Height to Node Ratio at early bloom - HNREB	14.00	
Soil Texture - ST	13.59	6
HUAP for harvest date - HUHD	13.29	
Open Bolls / meter - OBM	13.07	
Fruit retention at peak bloom - FRPB	11.85	
Height to Node Ratio at pin head square - HNRPHS	10.31	
Fruit Retention at pin head square - FRPHS	10.14	
Nodes at early bloom - NodesEB	9.99	
Height to Node Ratio at harvest - HNRF	9.92	
Fruit Retention at early bloom	9.10	
Nodes above cracked boll - NACB	6.43	
Bolls / meter - BM	4.93	
Average number of bolls per plant - BP	4.27	
Plants/meter - PM	4.02	
Nodes at pin head square - NodesPHS	3.39	
Nodes Final - NF	3.13	
First fruiting branch at harvest - FFBF	1.76	
First fruiting branch at early bloom - FFBEB	1.73	
Transgenic	1.69	4
First fruiting branch at cut out - FFBCO	1.56	
First fruiting branch at peak bloom - FRPB	0.95	
First fruiting branch at pin head square - FFBPHS	0.00	
Fruit retention at harvest - FRF	0.00	

Table 5. Loadings (L) and Eigenvectors (W) of the PC axes from PC analysis of data of cotton variables. Eigenvalues and their contribution to total variation are listed at bottom of the Table, 2000-2002.

	PC 1		**PC 2**		**PC 3**		**PC 4**		**PC 5**		**PC 6**		**PC 7**		**PC 8**		**PC 9**	
Variables	**L**	**W**	**L**	**W**	**L**	**W**	**L**	**W**	**L**	**W**	**L**	**W**	**L**	**W**	**L**	**W**	**L**	**W**
HUBCOUNT	-0.23	0.17	0.82	-0.02	0.38	-0.35	-0.02	-0.02	0.03	0.05	0.07	0.14	-0.21	-0.08	-0.12	-0.07	0.08	0.13
HUPHS	-0.05	0.23	0.75	-0.01	0.45	-0.29	-0.07	0.05	-0.14	0.02	0.04	0.03	-0.22	-0.08	-0.33	0.04	0.13	-0.00
HNRPB	0.51	0.30	0.61	-0.09	-0.03	0.08	-0.17	-0.09	-0.42	0.04	-0.14	0.12	-0.06	-0.06	-0.13	0.01	-0.11	0.03
HNREB	0.39	0.24	0.60	-0.17	-0.22	0.08	-0.26	-0.16	-0.38	0.09	-0.15	0.13	-0.11	0.02	-0.09	0.02	-0.23	0.01
NACB	0.04	0.23	0.58	0.06	0.52	-0.19	0.08	-0.09	-0.21	-0.10	-0.23	0.02	-0.12	-0.11	-0.22	0.12	-0.01	-0.03
NODESPB	-0.15	0.12	0.23	0.17	0.85	-0.22	0.10	0.20	0.03	-0.16	0.16	-0.01	-0.03	0.00	-0.09	-0.04	0.00	0.05
HUCO	0.31	0.20	0.16	0.21	0.76	-0.04	0.16	0.03	-0.23	-0.23	-0.31	-0.11	0.07	-0.22	-0.18	0.07	0.08	-0.04
NODESCO	0.08	0.12	0.10	0.20	0.72	-0.18	0.20	0.05	0.04	-0.15	0.09	-0.08	-0.40	0.25	0.08	-0.15	0.03	0.12
YIELD	0.35	0.08	0.18	0.20	0.46	-0.09	0.43	-0.03	0.32	0.12	-0.11	0.03	-0.17	0.01	0.05	-0.06	0.26	0.18
FRFINAL	-0.22	0.00	0.29	-0.31	-0.50	0.04	-0.29	-0.04	-0.23	0.06	0.14	0.23	0.23	0.01	-0.02	0.20	-0.34	-0.07
FRPB	-0.24	-0.17	0.01	-0.09	-0.53	0.05	0.04	-0.19	0.27	0.15	-0.05	0.21	0.17	-0.07	0.42	-0.05	-0.05	0.25
HUP-IT	-0.10	-0.09	-0.03	0.26	0.08	-0.08	0.96	-0.13	0.14	-0.08	-0.01	0.40	0.03	0.07	0.08	0.20	0.04	-0.11
HUJ-IT	-0.23	-0.13	-0.10	0.23	0.04	-0.08	0.93	-0.12	0.11	-0.12	0.01	0.39	0.09	0.06	0.07	0.23	0.02	-0.15
NODESF	0.36	-0.02	-0.24	0.30	0.15	0.10	0.76	-0.06	0.15	0.00	-0.05	0.21	-0.01	0.17	-0.03	0.12	-0.08	-0.20
HUF	0.35	-0.02	-0.26	0.36	0.30	0.07	0.71	-0.12	0.18	-0.05	-0.26	0.08	-0.03	0.03	0.09	0.03	0.10	-0.03
L4MIC	0.08	-0.14	-0.18	0.18	0.02	-0.02	0.24	0.05	0.83	0.40	0.06	0.04	0.14	-0.00	0.02	-0.05	0.01	-0.01
R50MIC	-0.22	-0.20	-0.14	0.11	-0.11	-0.11	0.14	-0.04	0.82	0.37	0.01	-0.03	-0.00	-0.03	0.06	-0.10	0.13	0.05
T4MIC	-0.16	-0.17	-0.17	0.08	-0.14	-0.07	0.04	-0.08	0.82	0.41	-0.10	-0.10	-0.00	-0.03	-0.04	-0.11	-0.03	-0.09
HNRF	0.23	0.15	0.23	-0.13	-0.24	0.08	-0.23	-0.23	-0.46	-0.10	-0.22	-0.07	-0.41	0.14	0.07	-0.16	-0.10	0.06
FFBCO	-0.31	-0.03	0.20	-0.08	0.09	-0.20	-0.02	0.35	0.05	-0.00	0.75	0.25	-0.04	0.18	-0.03	-0.12	0.03	0.03
FFBEB	-0.05	-0.10	-0.17	-0.04	-0.07	0.01	-0.05	0.43	-0.03	-0.04	0.69	0.16	0.20	0.06	0.10	-0.10	0.24	0.15
FFBF	0.33	0.04	-0.23	-0.01	0.18	0.17	-0.15	0.36	-0.26	-0.15	0.39	0.05	0.33	0.03	0.03	0.01	-0.05	0.04
FREB	0.01	-0.12	-0.14	-0.03	-0.25	0.16	0.02	0.18	0.10	0.07	0.11	0.24	0.79	-0.40	0.04	0.16	0.02	-0.00
NODESPHS	-0.17	0.11	0.26	-0.06	0.15	-0.21	-0.06	-0.09	-0.09	0.01	0.05	-0.16	-0.63	0.38	-0.24	0.08	-0.04	-0.11
PM	-0.07	-0.12	-0.26	-0.01	-0.16	0.15	0.07	-0.19	-0.14	-0.23	-0.11	0.10	0.06	0.12	0.80	-0.05	-0.07	0.52
FFBPB	-0.18	-0.18	-0.32	0.03	-0.04	0.05	0.12	0.04	0.16	-0.12	0.26	0.16	0.10	0.16	0.60	-0.17	-0.10	0.33
FRPHS	0.00	-0.00	0.01	0.07	0.10	-0.10	0.01	0.25	0.07	0.12	0.13	-0.18	0.07	-0.13	-0.13	0.39	0.82	0.33
FRCO	-0.06	-0.03	-0.03	0.03	0.03	-0.02	0.05	0.07	0.02	-0.12	0.19	0.18	0.04	-0.17	-0.05	-0.64	-0.26	-0.31
FFBPHS	0.05	0.02	0.06	-0.11	-0.13	-0.04	-0.10	0.16	0.09	0.20	0.50	0.06	-0.30	0.54	-0.11	0.17	-0.20	-0.06
Eigenvalue	9.58		6.54		5.05		2.39		2.02		1.65		1.37		1.26		1.09	
% of total	31.0		21.1		16.3		7.7		6.5		5.3		4.4		4.1		3.5	