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15 July 2024

Kathy Choo
Director
CoTerra Environment
Level 1, 98 Colin St
West Perth, WA 6005

Dear Kathy,

Plantecology Consulting was commissioned to undertake the numerical analysis and assignment of plot data to existing Floristic Community Types of the Swan Coastal Plain for a site in Wattle Grove. The methods and results outlined below are based on the data as supplied on the 17th June 2024.

1 Introduction

The remnant vegetation of the southern Swan Coastal Plain (SCP) was surveyed by Gibson et al. (1994) to provide an understanding of the major floristic gradients across the region. The major plant communities (or FCTs) were defined by classifying the data according to the similarities in species composition between plots. When determining the FCT of a new record, a floristic analysis of species composition provides the most robust method that is consistent with the original classification. Presently, a single consistent method for the determination of FCTs for vegetation data in the Swan Coastal Plain is not available. Therefore, it is preferable to use multiple methods and compare the output for the most likely result. The methods used are those outlined in *Methods for Survey and Identification of Western Australian Threatened Ecological Communities* (DBCA 2024) being FCT assignment using the Gibson et al. (1994) and Keighery et al. (2012) datasets, and assignment by the minimum dissimilarity between the Wattle Grove plots and plots from the two regional datasets (nearest neighbour). All analyses described below were undertaken using R packages Cluster (Maechler et al 2019), Vegclust (De Cáceres et al. 2010), optpart (Roberts 2020) and Vegan (Oksanen et al. 2020).

2 Methods

2.1. Hierarchical Clustering Assignments

Hierarchical agglomerative clustering is the usual first stage in classifying vegetation data into community types. This involves calculating the similarity (or more often, the dissimilarity) between plots within the dataset and then sequentially fusing the plots into groups according to their similarity. This type of method was used in the analysis of the original Swan Coastal Plain dataset (Gibson et al. 1994) and to determine the conservation status of additional plots, data is often added to the original dataset and the analysis re-run (Environmental Protection Authority 2016). The direct use of the original dataset as the basis for assigning new plot data to the regional classification has some drawbacks, however. First, a hierarchical clustering only applies to the relationships between plots, and the relative distances between them, within that particular dataset. The addition of new data often alters the relative cophenetic distances and disrupts the clustering output. Second, as an unsupervised method, hierarchical clustering does not define rules for the membership of the defined groups, and so the addition of new plots requires the rebuilding of the entire hierarchy (De Cáceres and Wiser 2012).

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The data for the Swan Coastal Plain regional survey (Gibson et al. 1994) and that of Keighery et al. (2012) was downloaded from the NatureMap website. The current Gibson et al. (1994) dataset has been modified from that of the original survey with the removal of one site (OATES-1), resulting in a dataset of 508 plots. The Keighery et al. (2012) dataset is a compilation of data from a number of floristic studies and extended the Gibson et al. (1994) dataset. The composite dataset used in this analysis was that curated on the NatureMap website as of 2015. Notwithstanding the proviso in Keighery et al. (2012) that the composite dataset should not be used for FCT analyses, it can be useful when assigning new plot data that are potentially from FCT that were under-sampled in in the Gibson et al. (1994) survey e.g. FCT 14 and FCT 18.

The species nomenclature of the datasets was updated to be consistent with current usage. Where original names could not be matched clearly to the updated usage, those taxa were removed from the analysis. Infraspecies ranks were raised to species level when no matching rank had been used in the original datasets. Taxa that could not be identified to species level in the Wattle Grove dataset were removed.

The new data from the Wattle Grove survey was added to both Swan Coastal Plain datasets and the new dataset was then analysed using the Bray-Curtis distance coefficient (or resemblance measure) and the flexible beta linkage method (beta = -0.1). Assignment of the Wattle Grove plots was to the nearest distinct group by inspection of the resulting dendrogram. To examine any effect of spatial correlation between the new plots, data was also added to the matrix one plot a time and the analyses re-run.

In practice, there is often less similarity between a new plot and the plots of the FCT to which it is assigned than between the original plots themselves. That is, new plots are usually most similar to fringing members of the original group.

2.2. Nearest Neighbour

The nearest neighbour assignment method uses the minimum Bray-Curtis distance between a new plot and a plot from the original dataset. The comparison of individual samples is seldom useful as new plots are rarely similar to diagnostic plots from the original FCT classification. More often, the nearest neighbour is a fringe member of a FCT and may not be a 'near' neighbour, which regularly leads to misclassifications. Assignments to the nearest group (as in the clustering methods described above) are more robust.

3 Results

The cluster analysis of the Wattle Grove plots indicates that there are at least three vegetation units present at the Wattle Grove sites (Figure 1). Cluster 1 comprises Aecom plots 1, 7 10 and 11, Cluster 2 comprises Aecom plots 4, 6, 9 and 13 as well as JBSG 01, and Cluster 3 comprises Aecom plots 15, 18, 19 and 20.

When assigning all plots at once to the Gibson et al. (1994) and Keighery et al. (2012) datasets, a strong spatial correlation can be seen (Figures 2 and 3) as all Wattle Grove plots fused together as a group and without altering the structure seen in Figure 1.

Assignment to FCTs was more definitive for the single-plot analysis, with some variation in results between datasets (Figures 4-29). Plots from Cluster 1 are most likely members of FCT 3b '*Corymbia calophylla* – *Eucalyptus marginata* woodlands on sandy clay soils'. The assignments to both Swan Coastal Plain datasets were the same although that of Aecom 7 to the Keighery et al. (2012) dataset was more equivocal (Figure 20).

Plots from Cluster 2 were assigned to FCT 20c 'Eastern shrublands and woodlands', except for Aecom 15, which was assigned to FCT 3b by the Gibson et al. (1994) dataset, and S09 ('*Banksia attenuata*

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woodlands over dense low shrublands') or S16 ('Highly saline seasonal wetlands') when using the Keighery et al. (2012) dataset. The latter assignment appears unlikely.

Apart from Aecom 9, Cluster 3 plots were assigned to FCT 20a '*Banksia attenuata* woodlands over species rich dense shrublands'. Aecom 9 was clearly assigned to FCT 20c using the Gibson et al. (1994) dataset but were equivocal when assigning to the Keighery et al. (2012) dataset.

The presence of typical species for FCTs on the eastern side of the Swan Coastal Plain (DBCA 2024) supports the results of the cluster analysis. Typical species for FCT 3b such as *Gompholobium knightianum, Hakea stenocarpa, Hakea undulata* and *Xanthosia candida* were recorded for the Cluster 1 plots. Within the Cluster 2 plots, *Grevillea bipinnatifida* and *Podolepis gracilis* were both recorded and are typical for FCT 20c, and taxa typical for FCT 20a such as *Conospermum undulatum, Conothamnus trinervis, Isopogon autumnalis, Hemiphora bartlingii* and *Xanthorrhoea acanthostachya* were all present within Cluster 3 plots.

In determining probable FCTs for the Wattle Grove dataset, most weight was given to assignment to the Gibson et al. (1994) dataset, as this produced clearer and more consistent results (Table 1). While assignment to the Keighery et al. (2012) dataset was mostly similar, more disruption to the original classification was observed, with a consequent reduction in confidence of the results. Least weight was given to the nearest neighbour assignments as these were less consistent with the results of the clustering analyses, and none were less 0.5. The cross tabulation of the Bray Curtis dissimilarities between the Swan Coastal Plain and the Wattle Grove plots is shown on Table 2.

Table 1: Floristic Community Type assignment summary.

Plot	Assignment to Gibson et al. (1994)	Assignment to Keighery et al. (2012)	Nearest Neighbour	Probable FCT
AECOM_1_outside	3b	3b	20b	3b
AECOM_4	20a	20a	20a	20a
AECOM_6	20a	20a	20c	20a
AECOM_7_outside	3b	3/20	3b	3b
AECOM_9	20c	Undetermined	20c	20c
AECOM_10_outside	3b	3b	3b	3b
AECOM_11_outside	3b	3b	3b	3b
AECOM_13	20a	20a	20a	20a
AECOM_15_outside	3b	S09/S16	20c	3b
AECOM_18_outside	20c	20b	20b	20c
AECOM_19_outside	20c	20c	20b	20c
AECOM_20_outside	20c	Undetermined	20b	20c
JBSG_S01	20a	20a	20a	20a

4 Discussion

The results of the cluster assignments show that three FCTs are present within the Wattle Grove dataset - FCTs 3b, 20a and 20c. All are listed as Threatened Ecological Communities pursuant to the *Biodiversity Conservation Act 2016.* FCT 20c is also listed as an Endangered TEC pursuant to the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), with FCT 20a forming part of the Endangered 'Banksia woodlands of the Swan Coastal Plain ecological community' TEC. FCT 3b is not listed under the EPBC Act.

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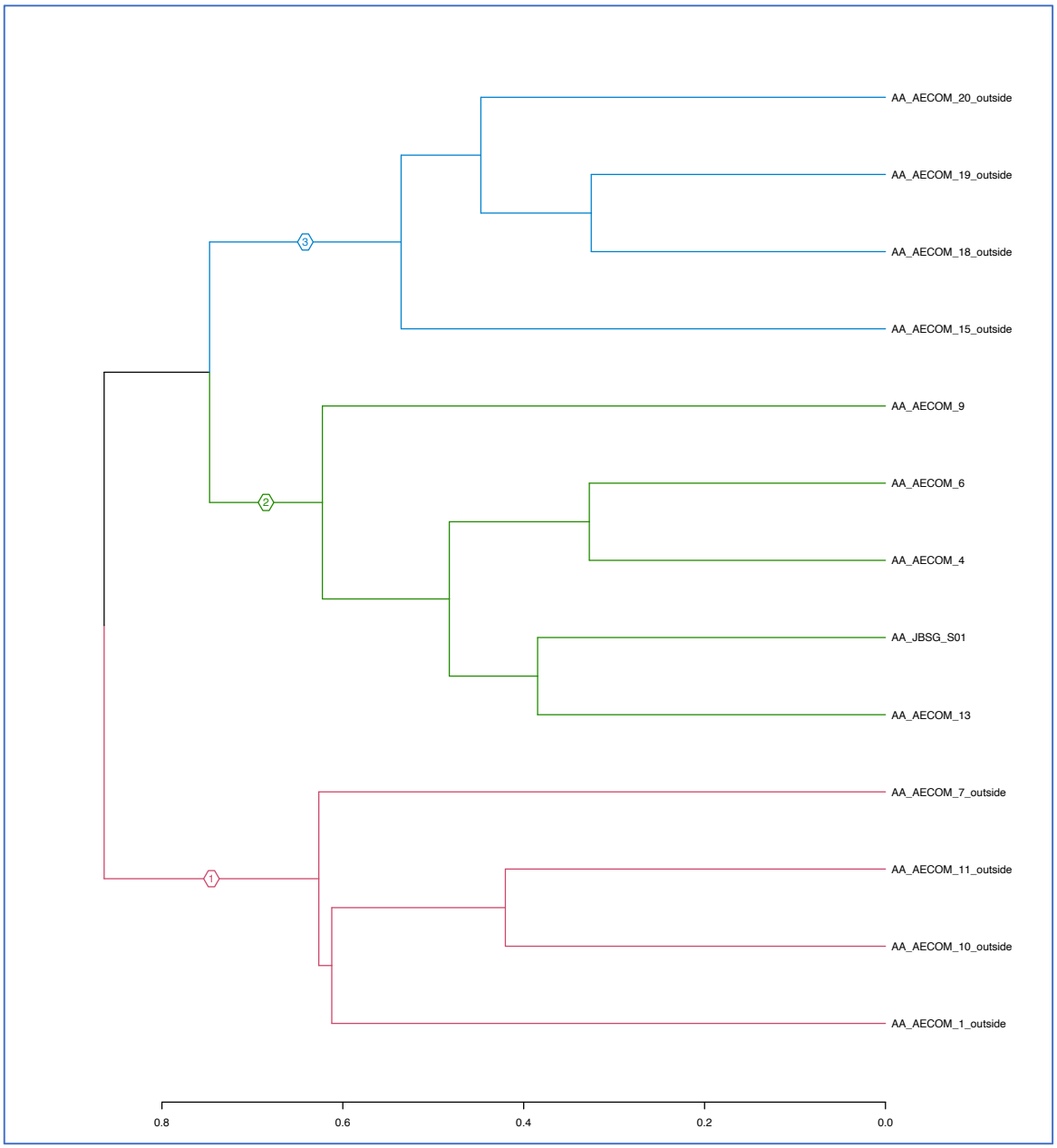

Figure 1: Dendrogram of Wattle Grove plots.

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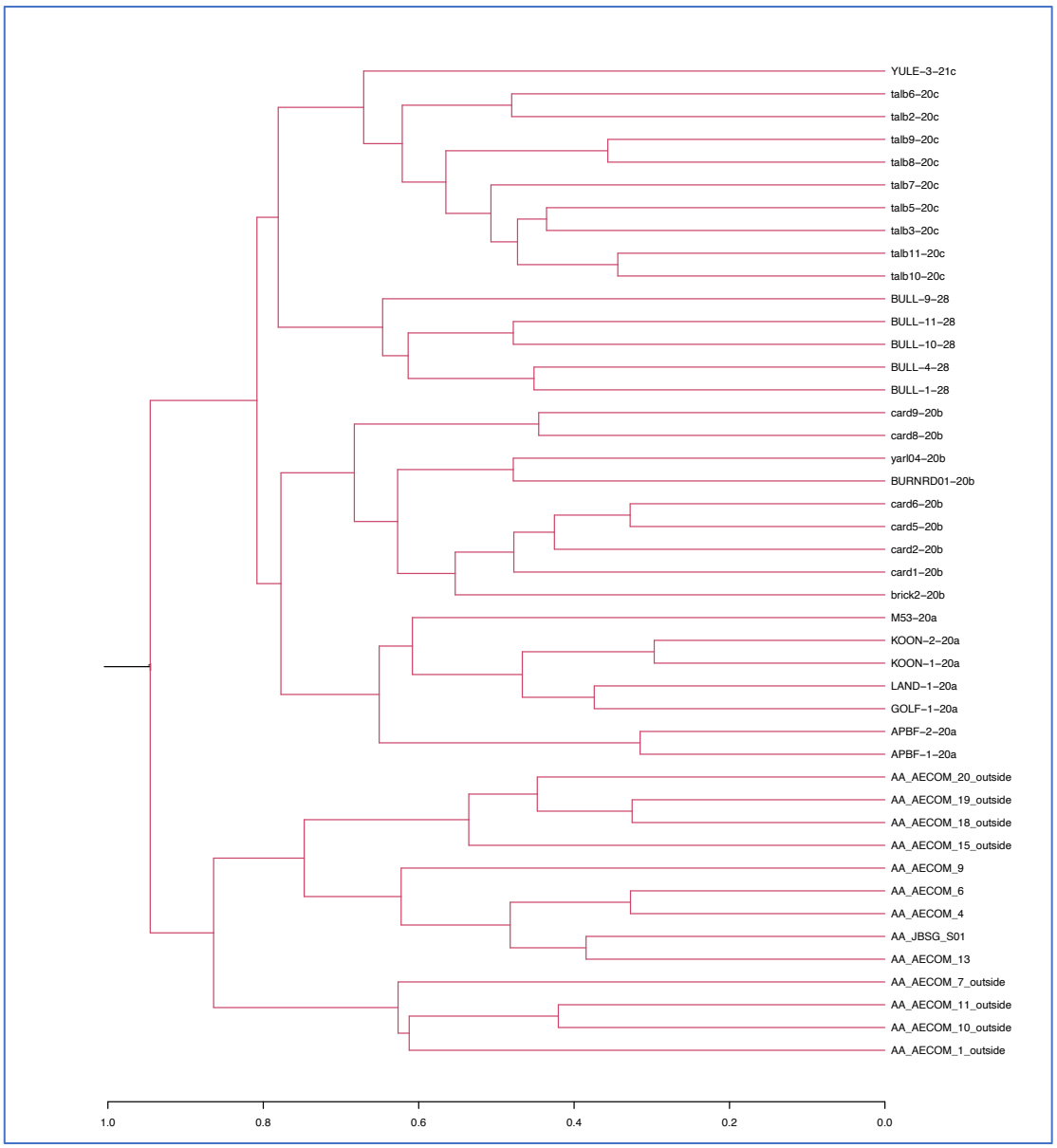

Figure 2: Partial dendrogram for the assignment of the Wattle Grove plots to the Swan Coastal Plain floristic community types.

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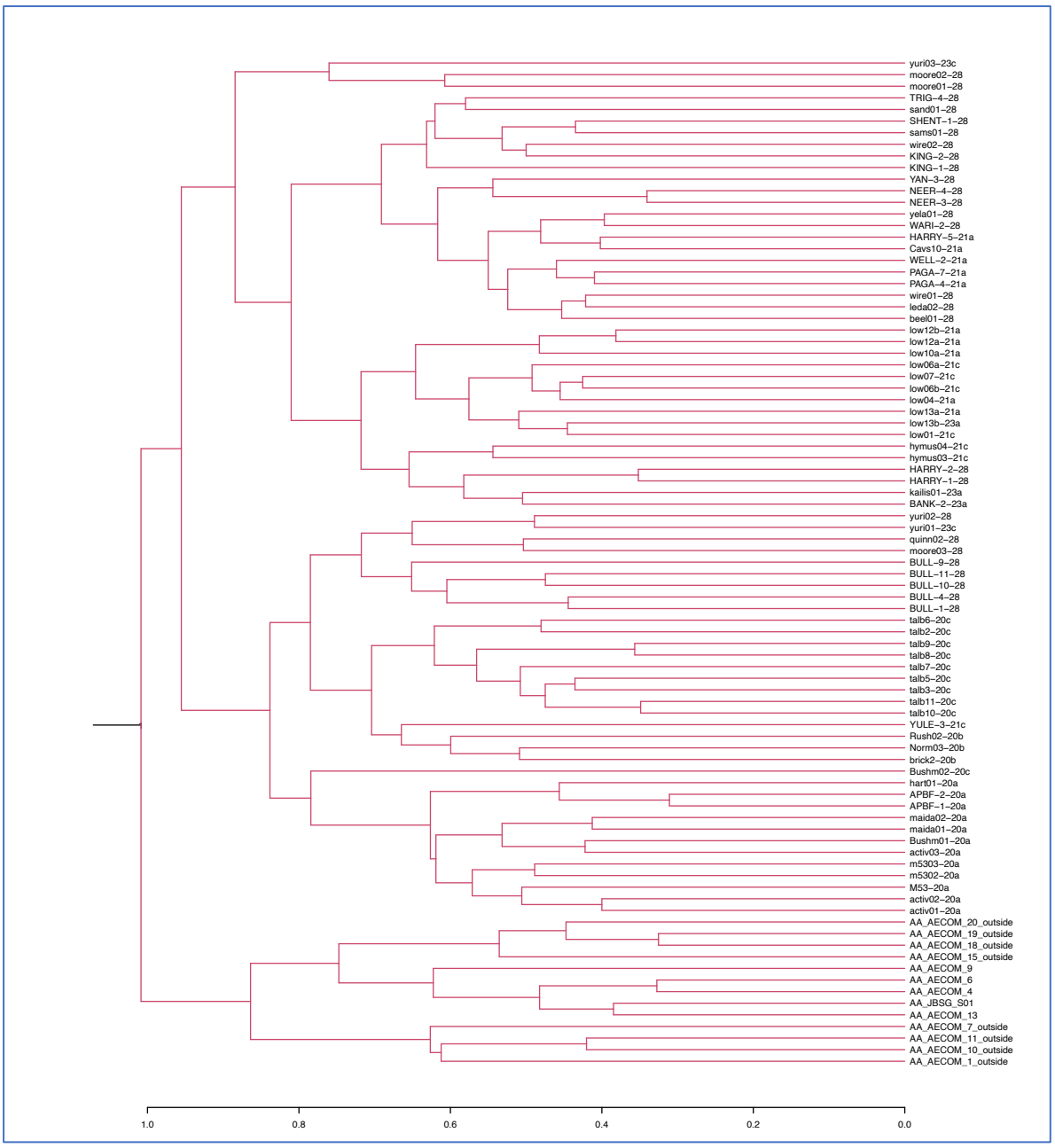

Figure 3: Partial dendrogram for the assignment of the Wattle Grove plots to the Keighery et al. (2012) floristic community types.

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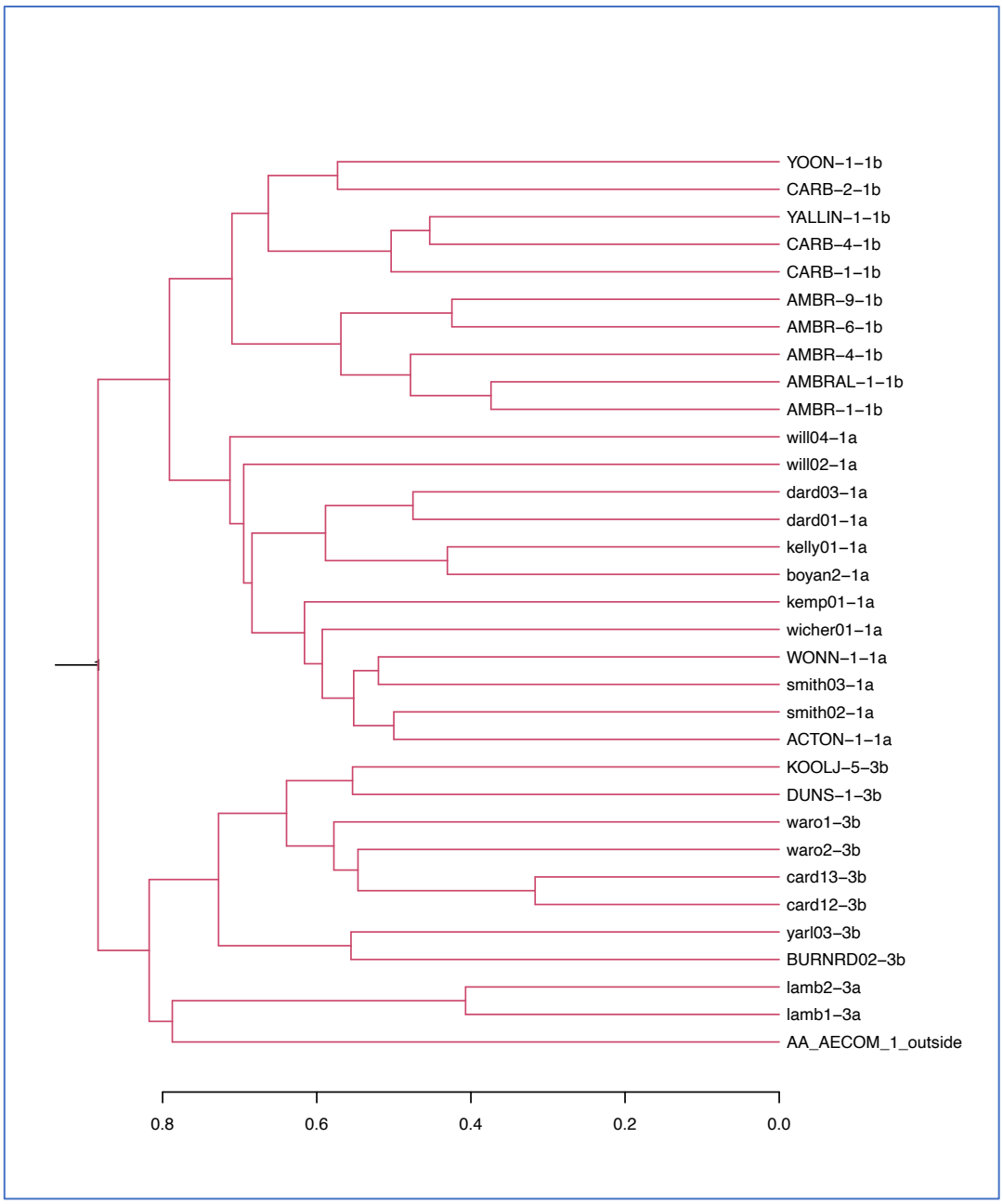

Figure 4: Partial dendrogram for the assignment of plot AECOM_1 to the Swan Coastal Plain floristic community types.

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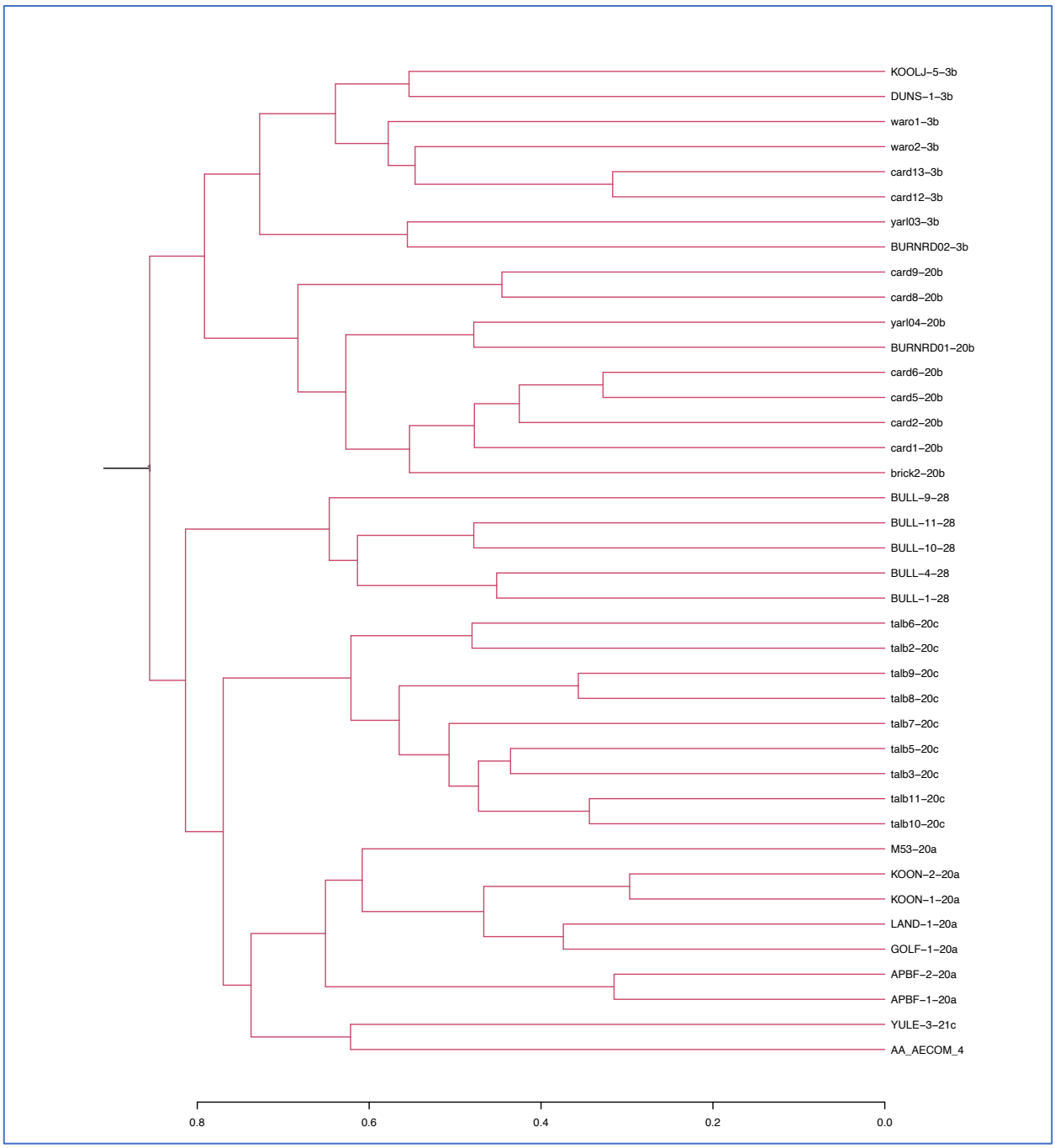

Figure 5: Partial dendrogram for the assignment of Plot AECOM_4 to the Swan Coastal Plain floristic community types.

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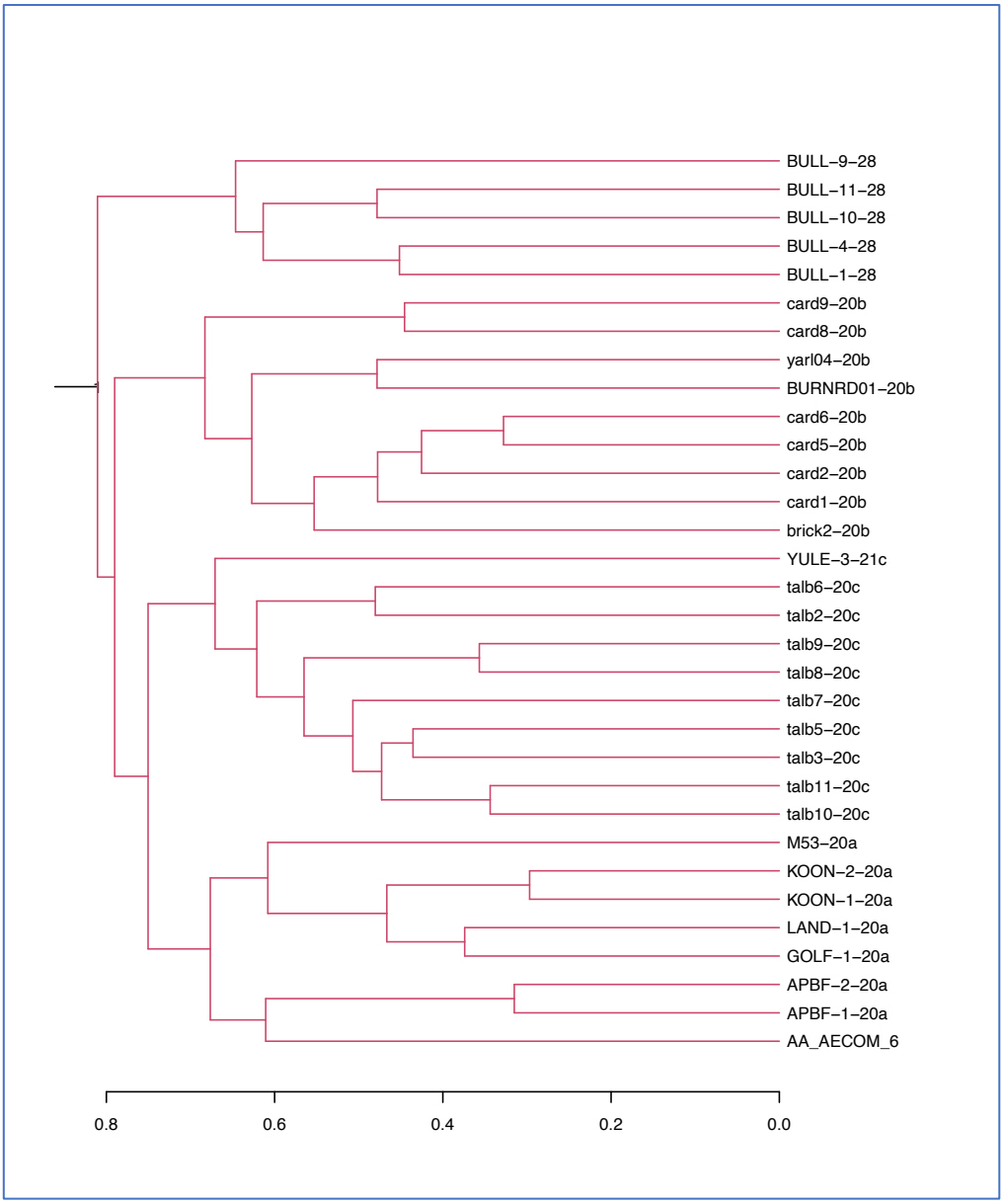

Figure 6: Partial dendrogram for the assignment of Plot AECOM_6 to the Swan Coastal Plain floristic community types.

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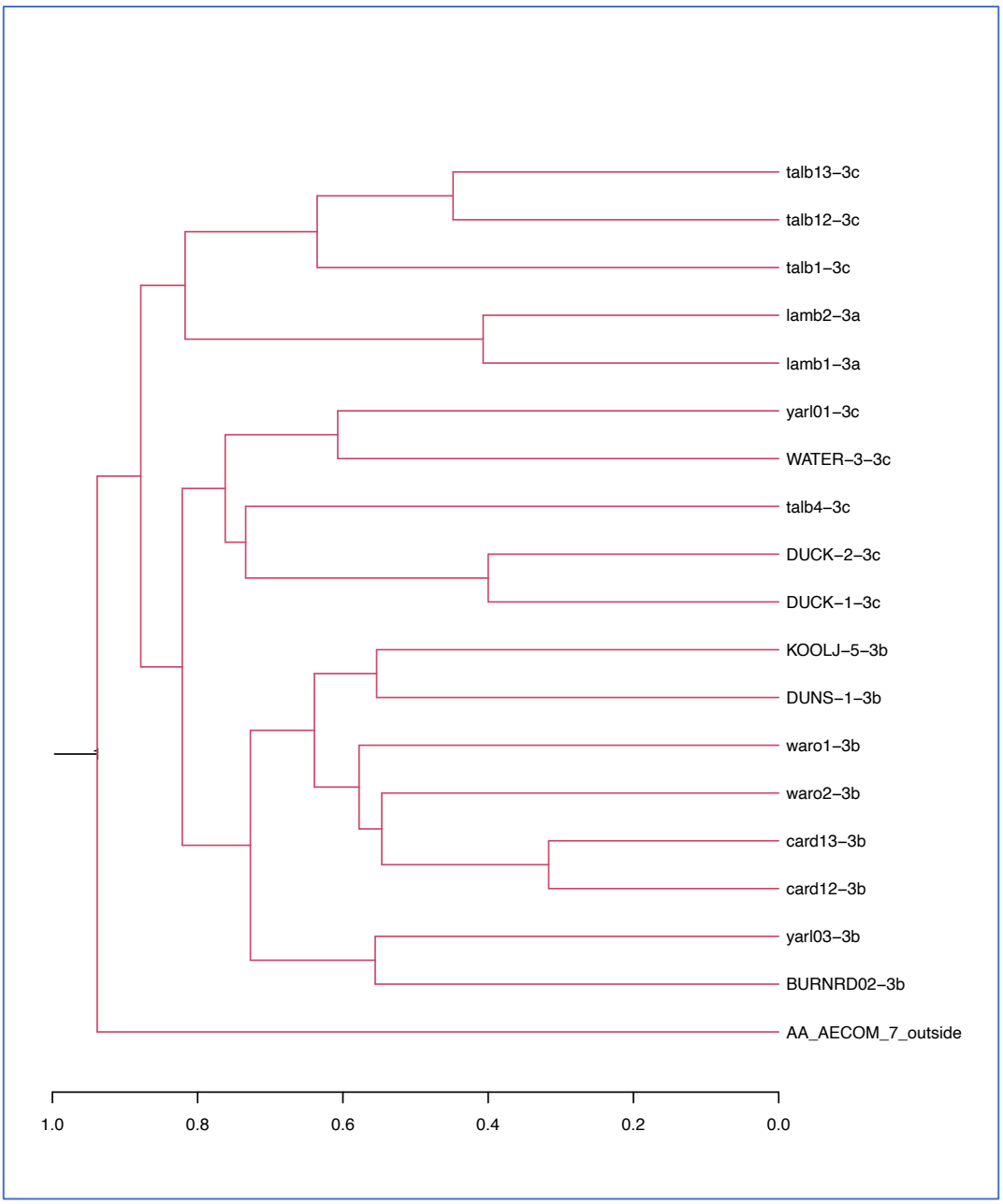

Figure 7: Partial dendrogram for the assignment of Plot AECOM_7 to the Swan Coastal Plain floristic community types.

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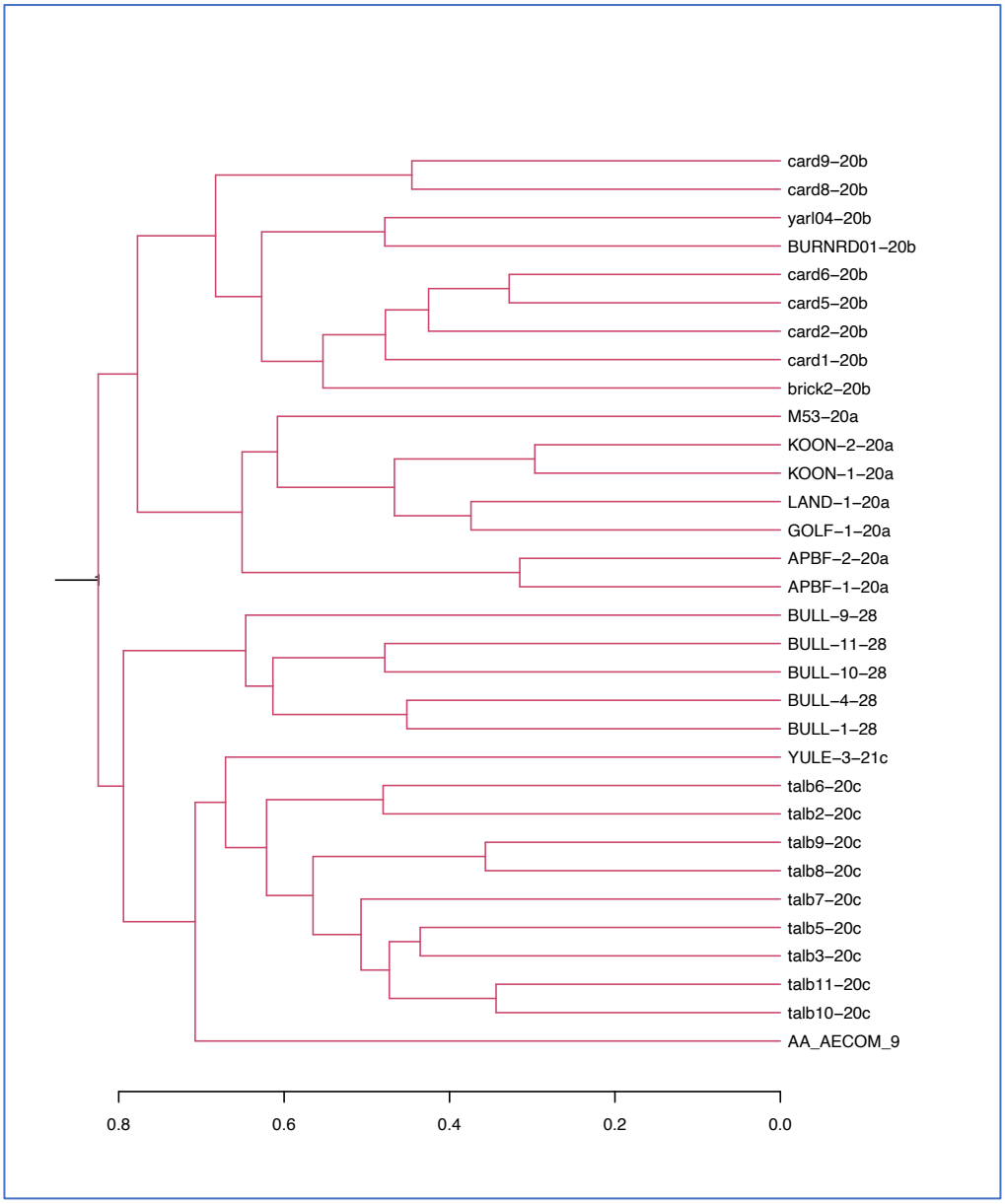

Figure 8: Partial dendrogram for the assignment of Plot AECOM_9 to the Swan Coastal Plain floristic community types.

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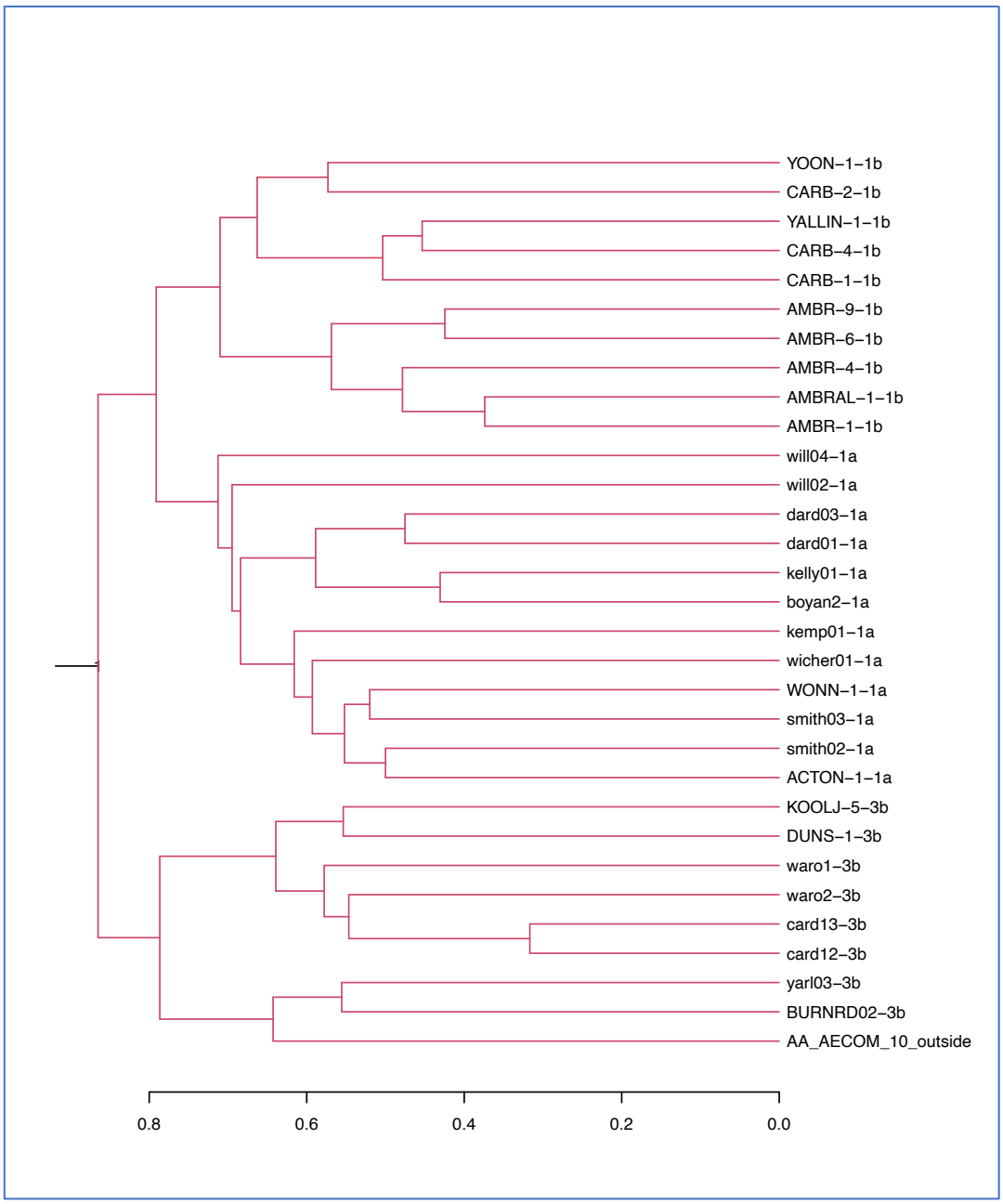

Figure 9: Partial dendrogram for the assignment of Plot AECOM_10 to the Swan Coastal Plain floristic community types.

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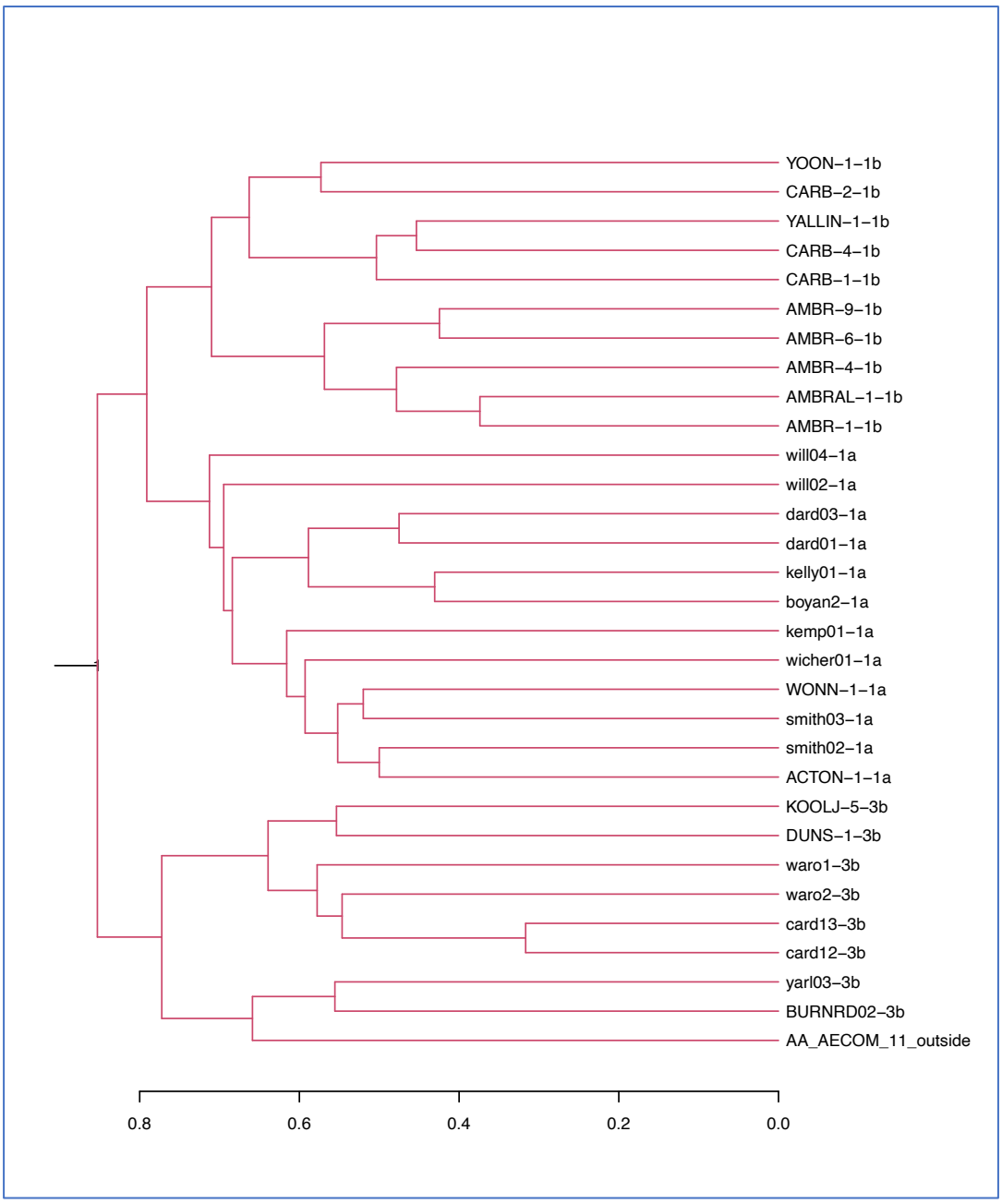

Figure 10: Partial dendrogram for the assignment of Plot AECOM_11 to the Swan Coastal Plain floristic community types.

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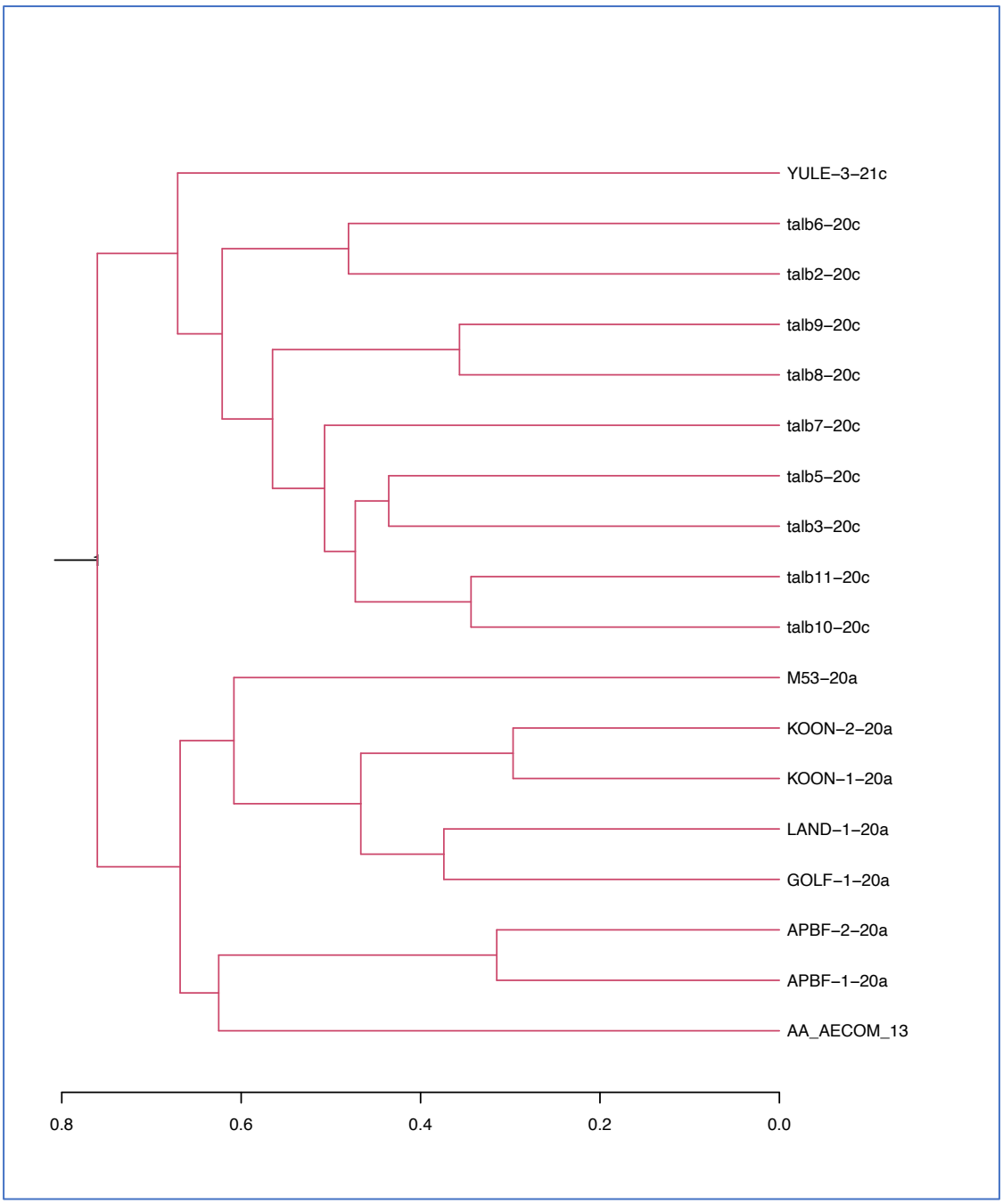

Figure 11: Partial dendrogram for the assignment of Plot AECOM_4 to the Swan Coastal Plain floristic community types.

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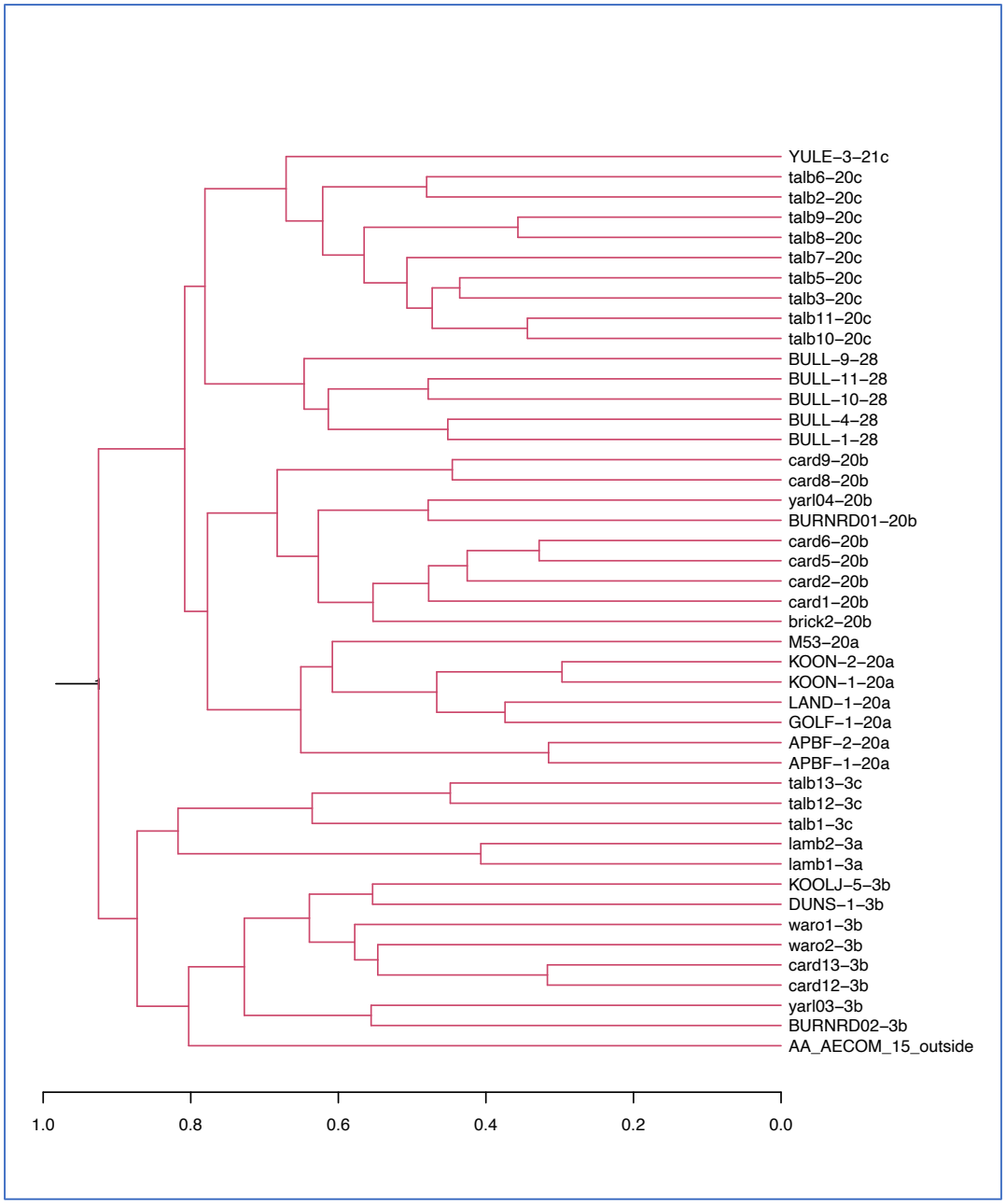

Figure 12: Partial dendrogram for the assignment of Plot AECOM_15 to the Swan Coastal Plain floristic community types.

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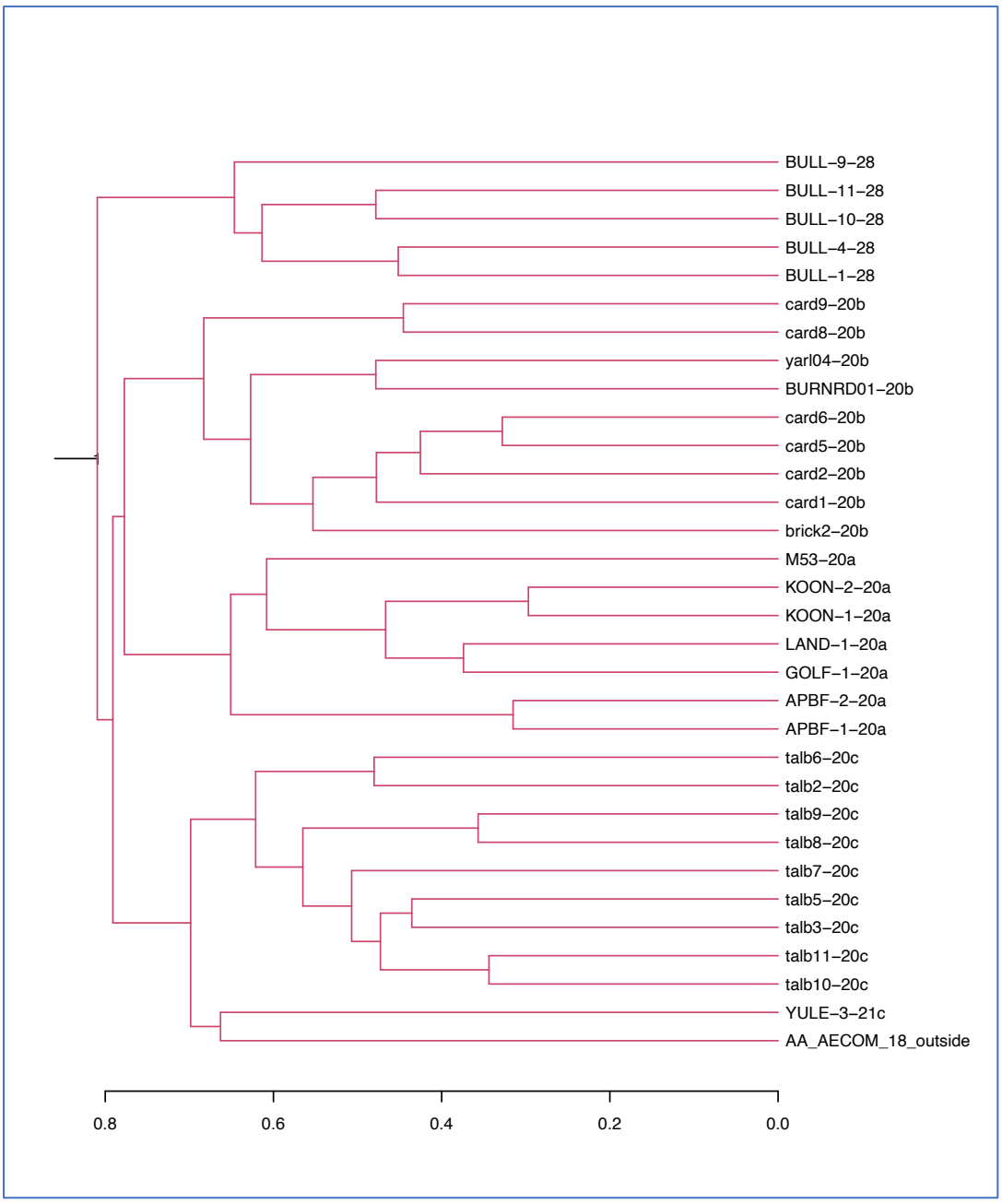

Figure 13: Partial dendrogram for the assignment of Plot AECOM_18 to the Swan Coastal Plain floristic community types.

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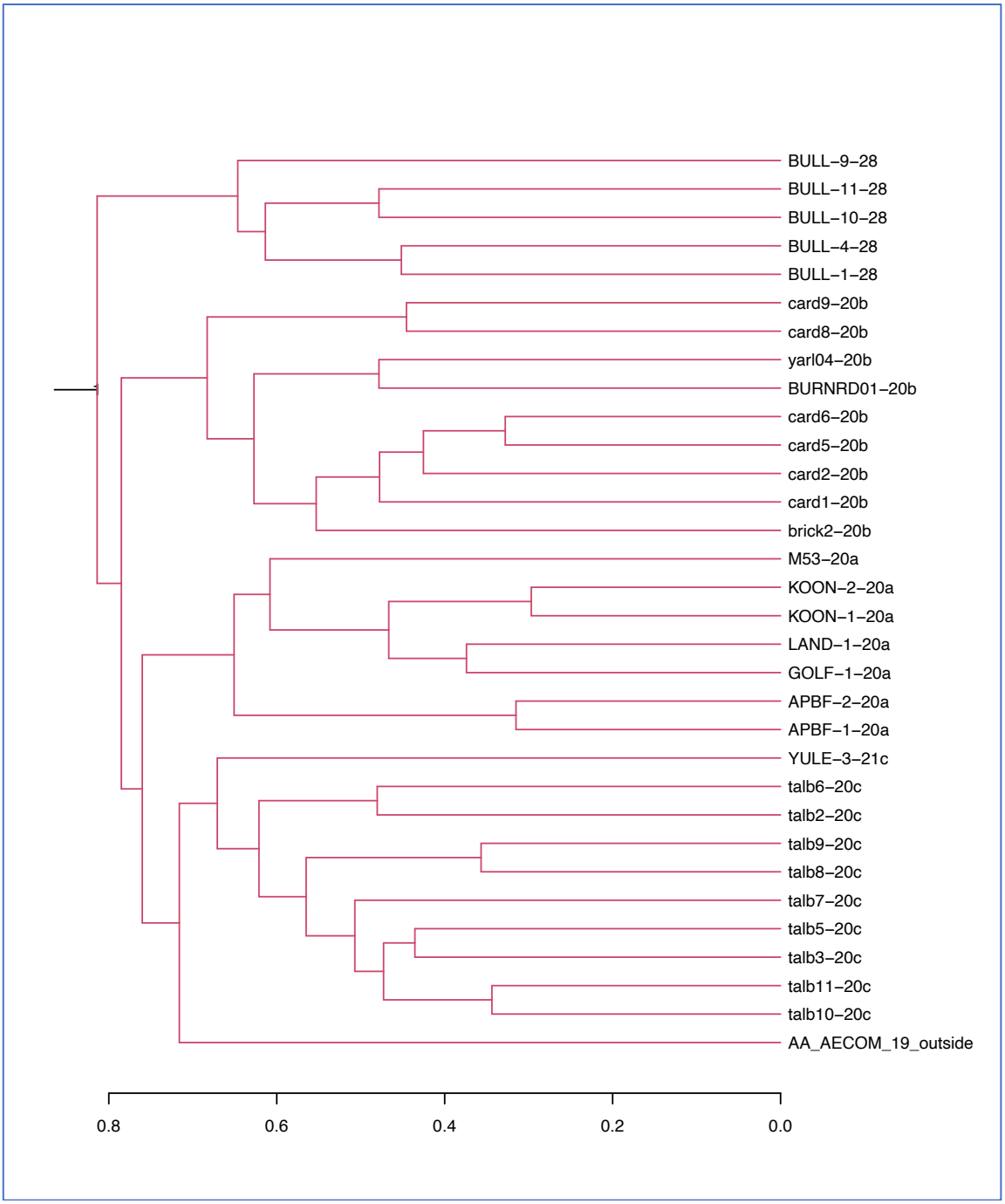

Figure 14: Partial dendrogram for the assignment of Plot AECOM_19 to the Swan Coastal Plain floristic community types.

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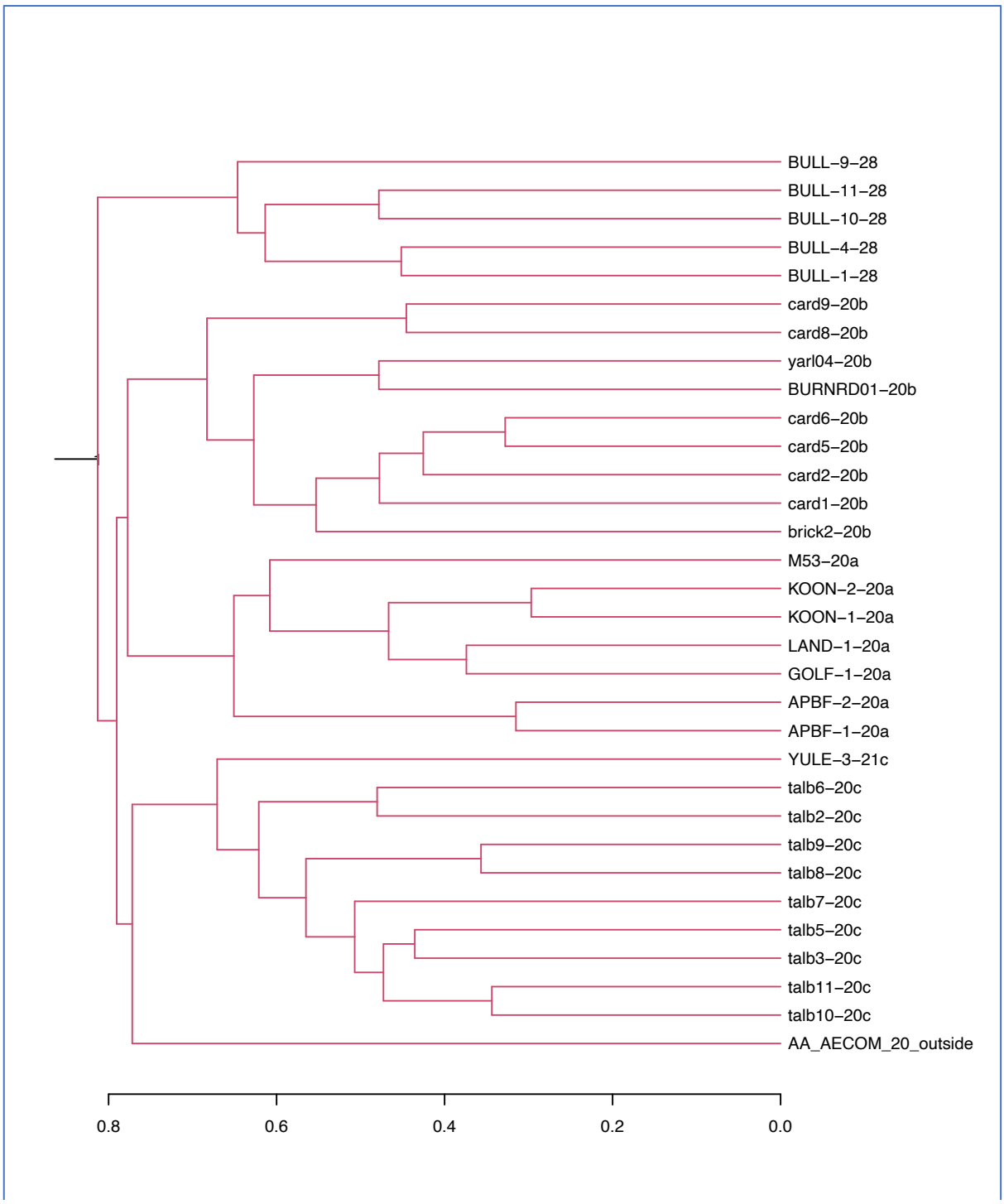

Figure 15: Partial dendrogram for the assignment of Plot AECOM_20 to the Swan Coastal Plain floristic community types.

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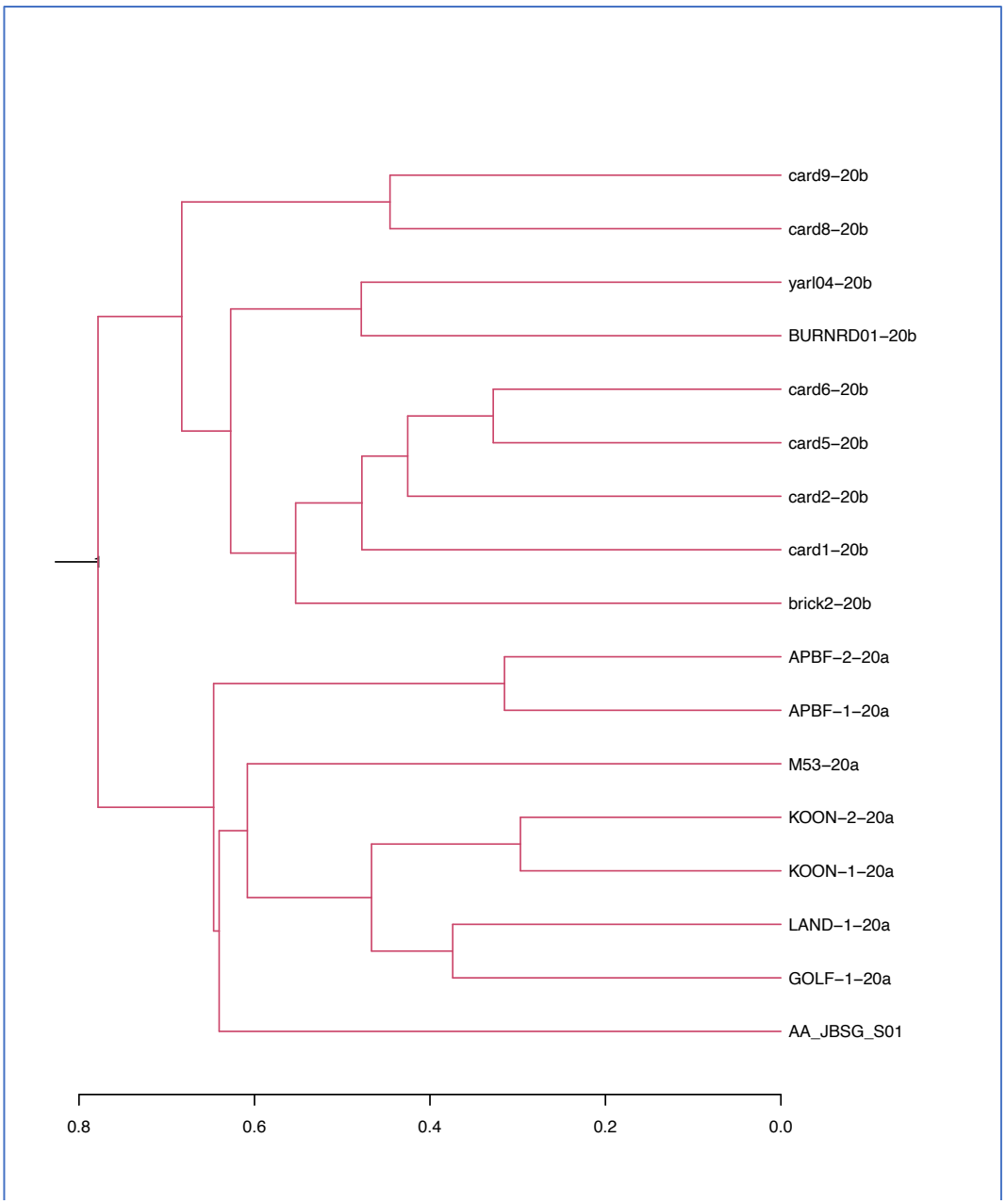

Figure 16: Partial dendrogram for the assignment of Plot JBSG_01 to the Swan Coastal Plain floristic community types.

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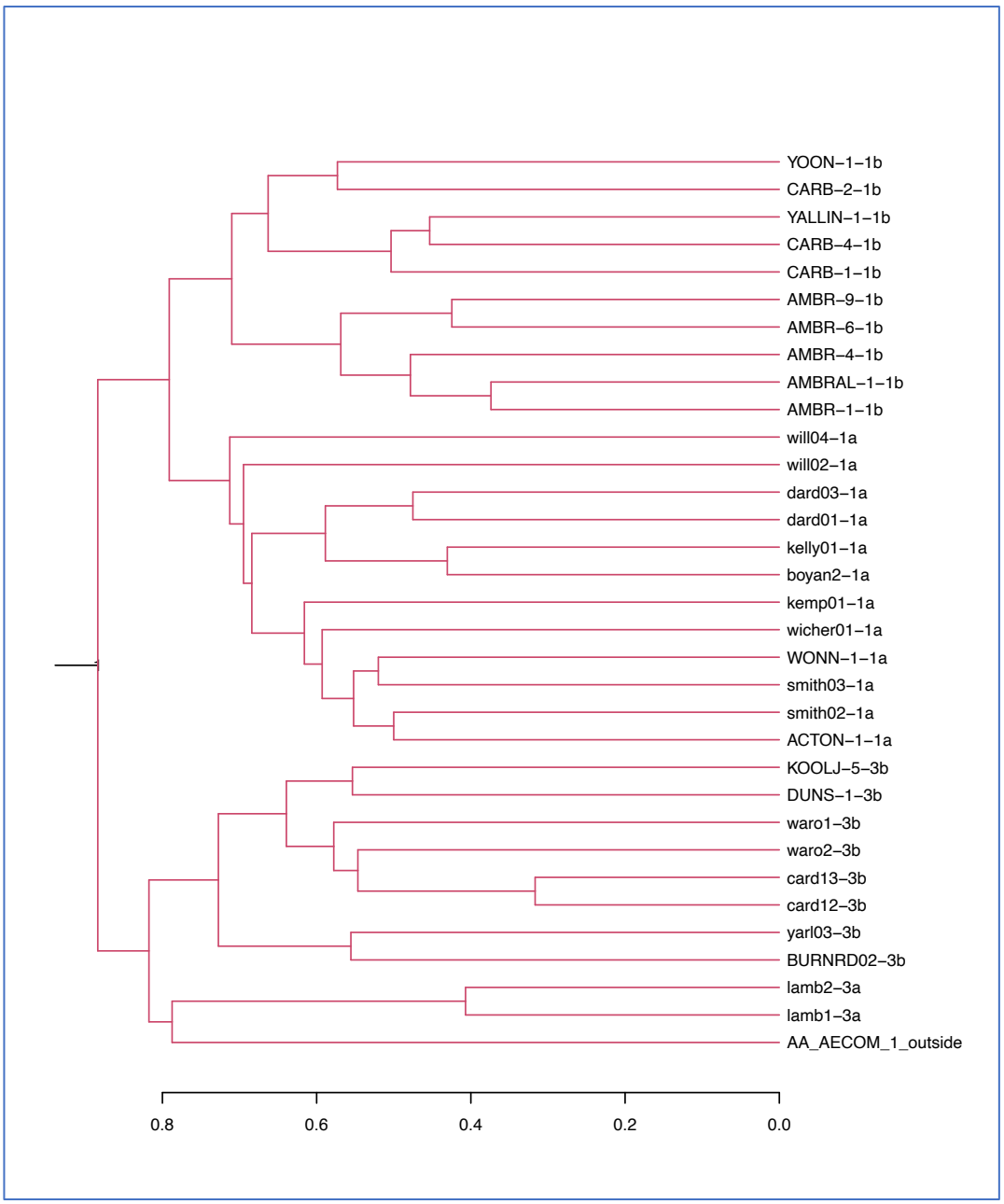

Figure 17: Partial dendrogram for the assignment of Plot AECOM_1 to the Keighery et al. (2012) floristic community types.

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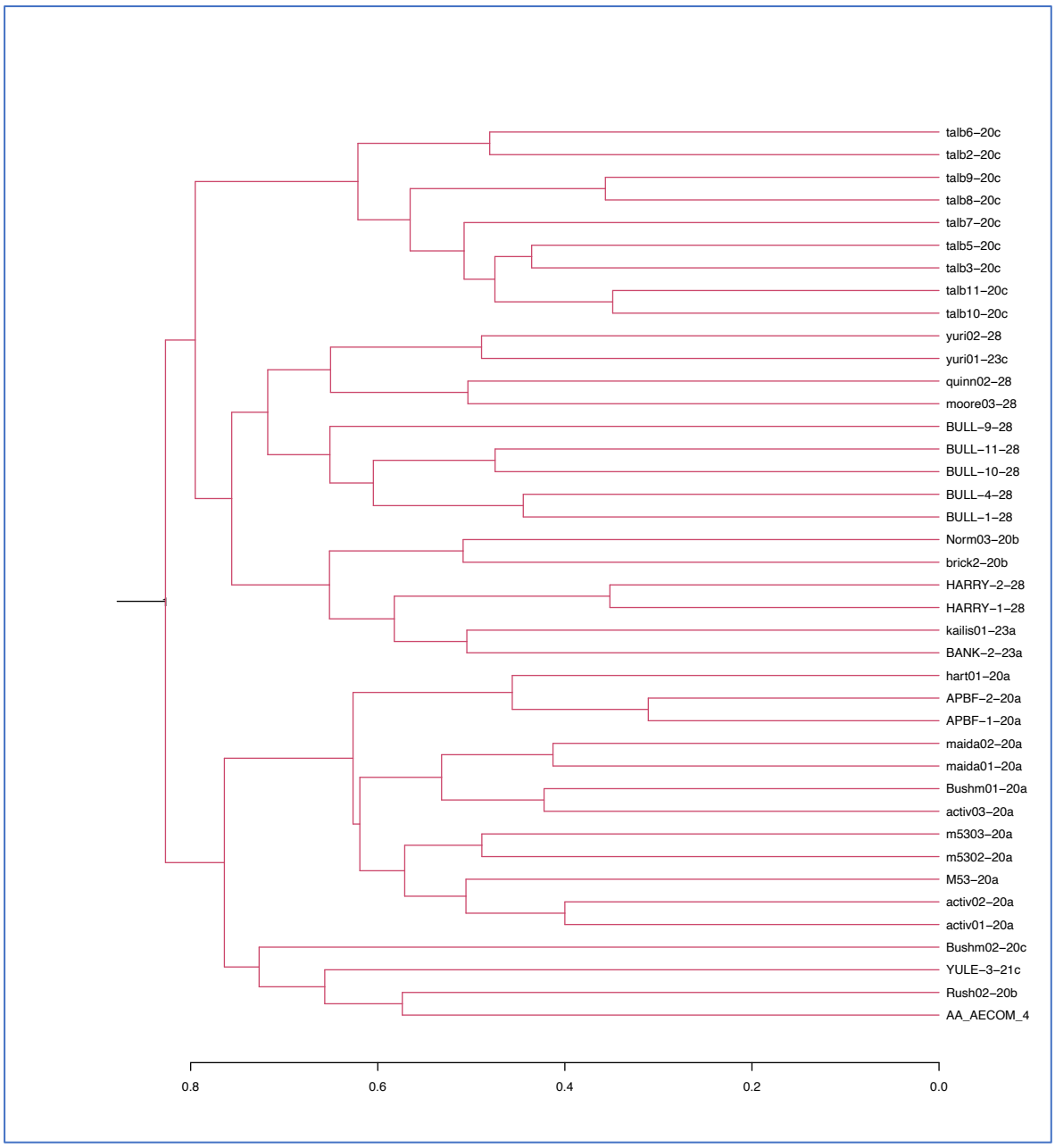

Figure 18: Partial dendrogram for the assignment of Plot AECOM_4 to the Keighery et al. (2012) floristic community types.

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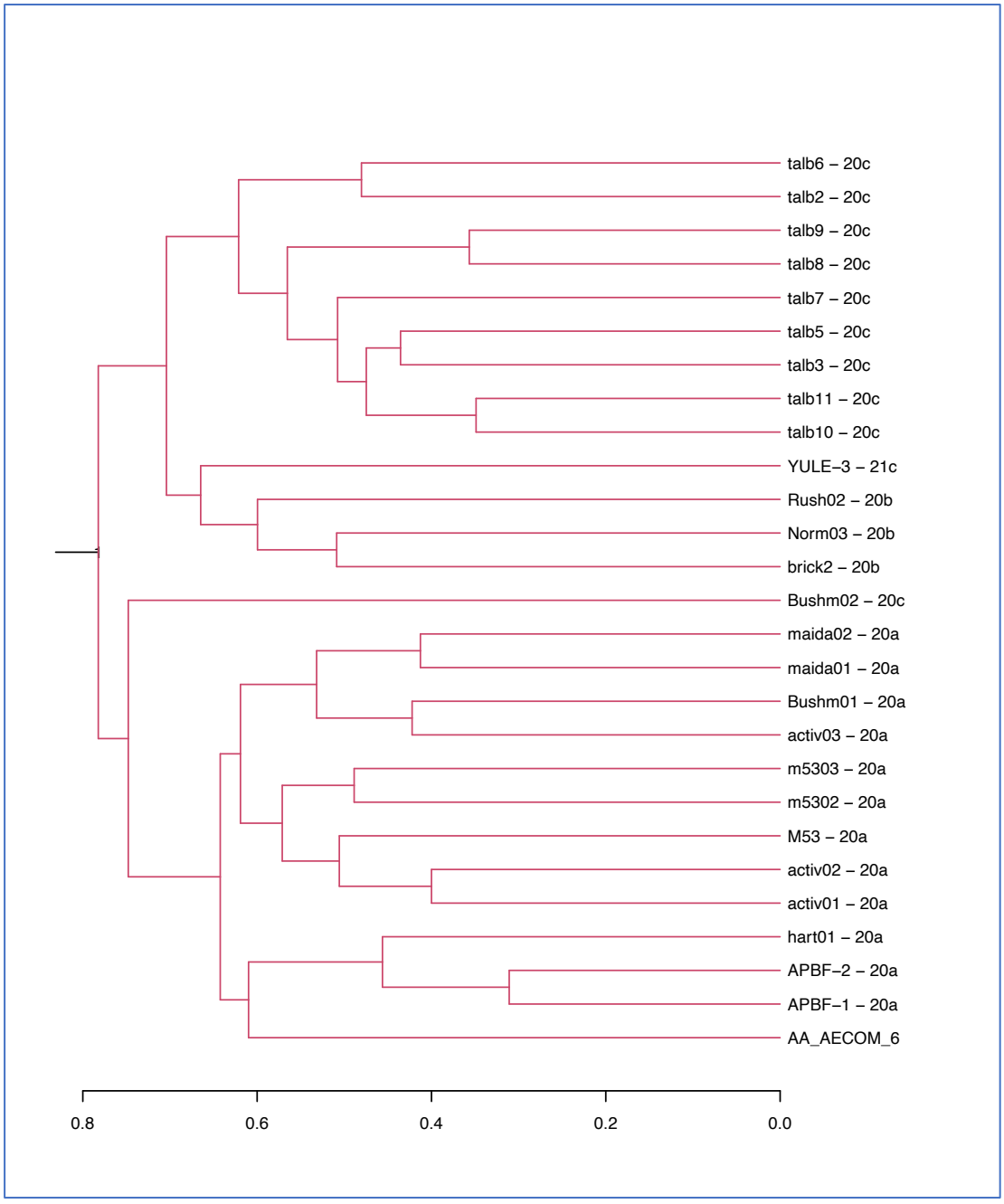

Figure 19: Partial dendrogram for the assignment of Plot AECOM_6 to the Keighery et al. (2012) floristic community types.

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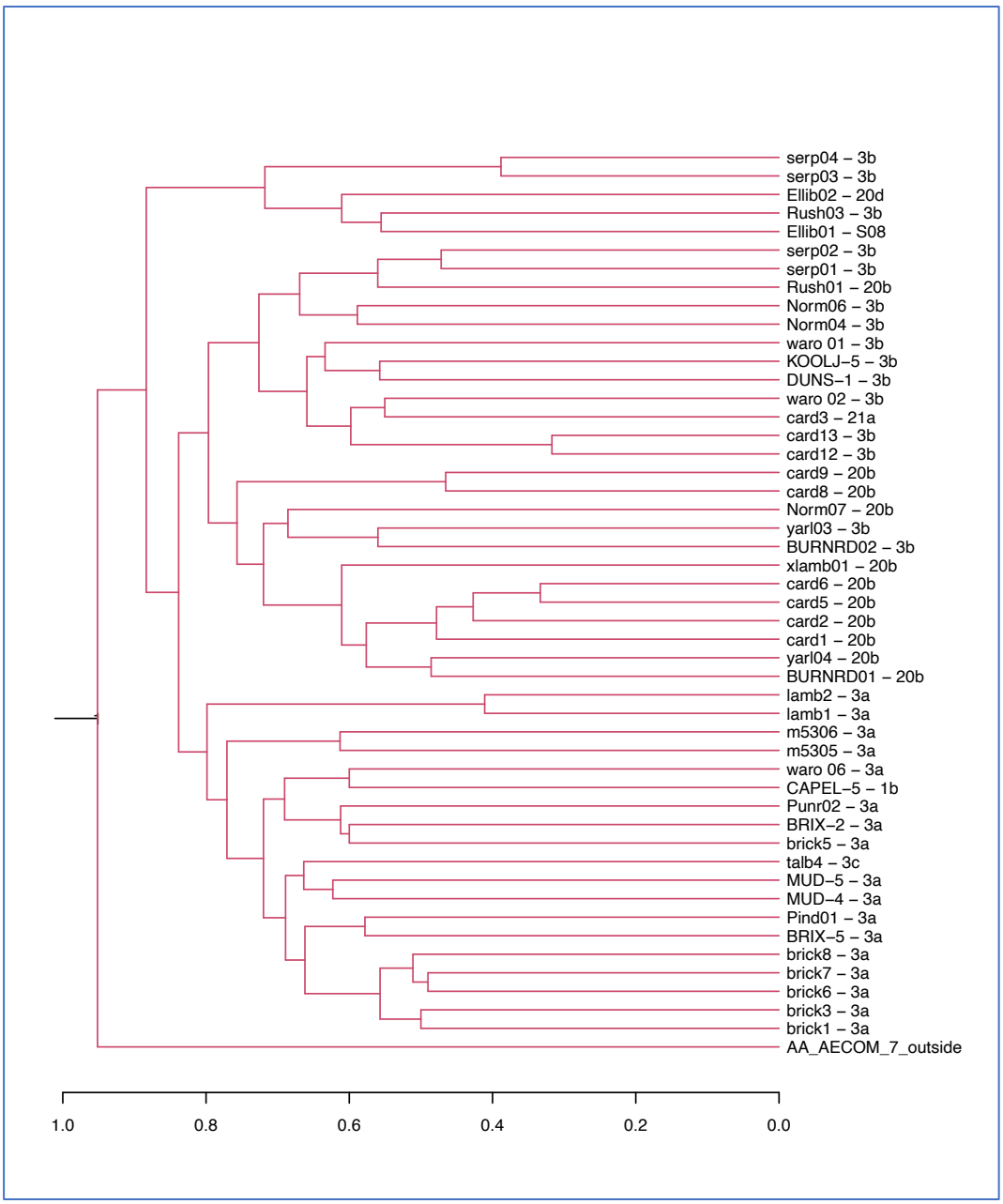

Figure 20: Partial dendrogram for the assignment of Plot AECOM_7 to the Keighery et al. (2012) floristic community types.

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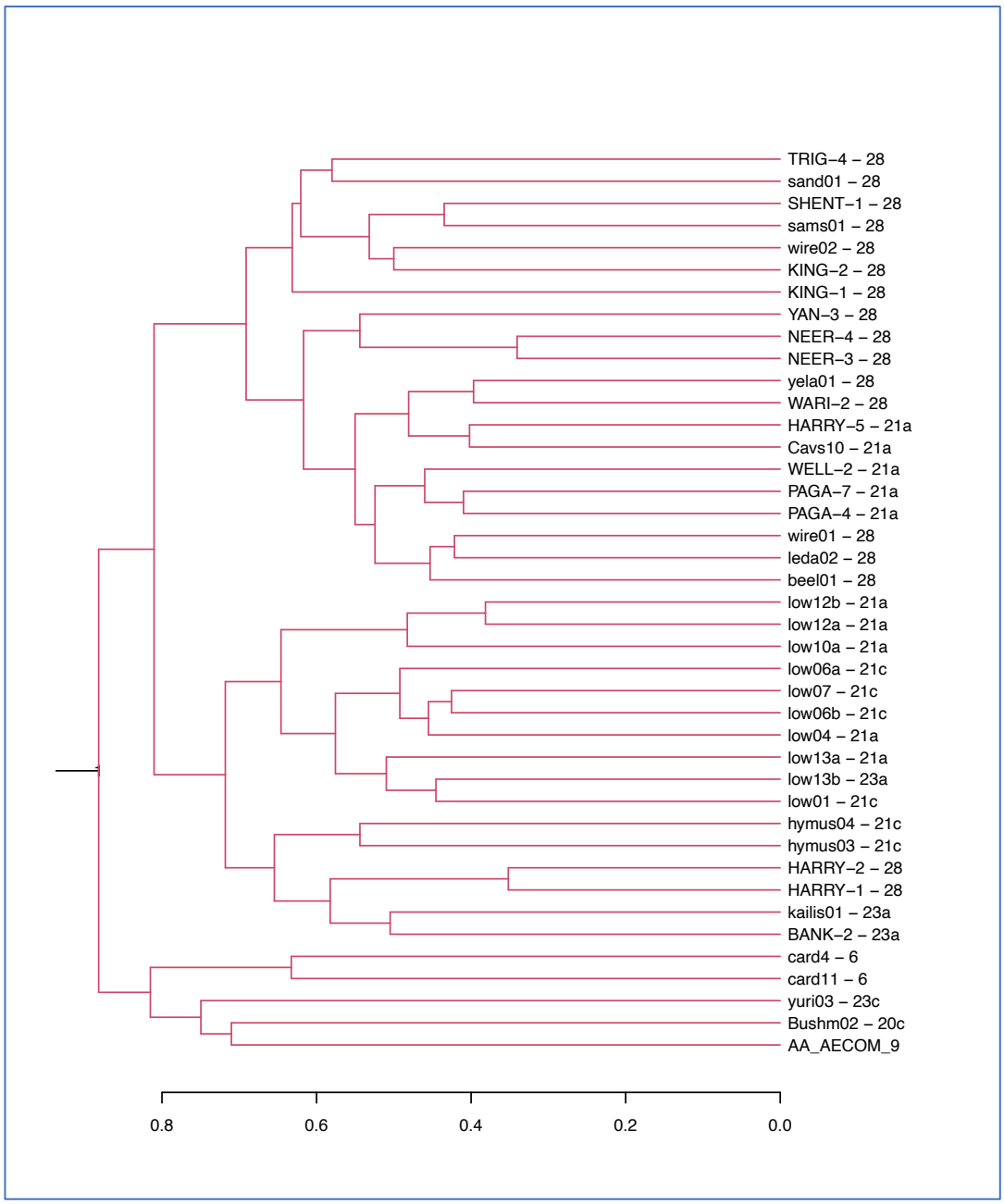

Figure 21: Partial dendrogram for the assignment of Plot AECOM_9 to the Keighery et al. (2012) floristic community types.

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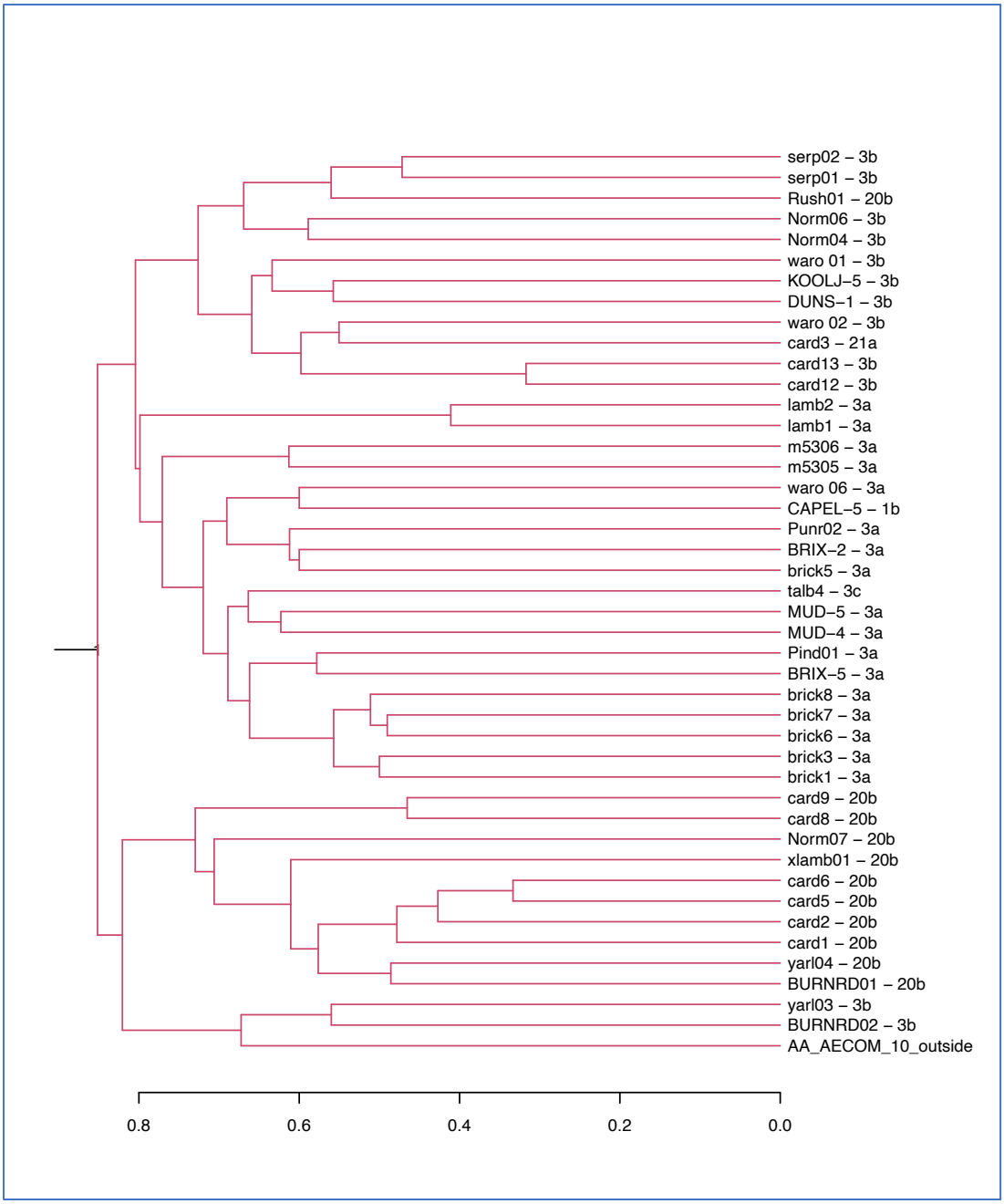

Figure 22: Partial dendrogram for the assignment of Plot AECOM_10 to the Keighery et al. (2012) floristic community types.

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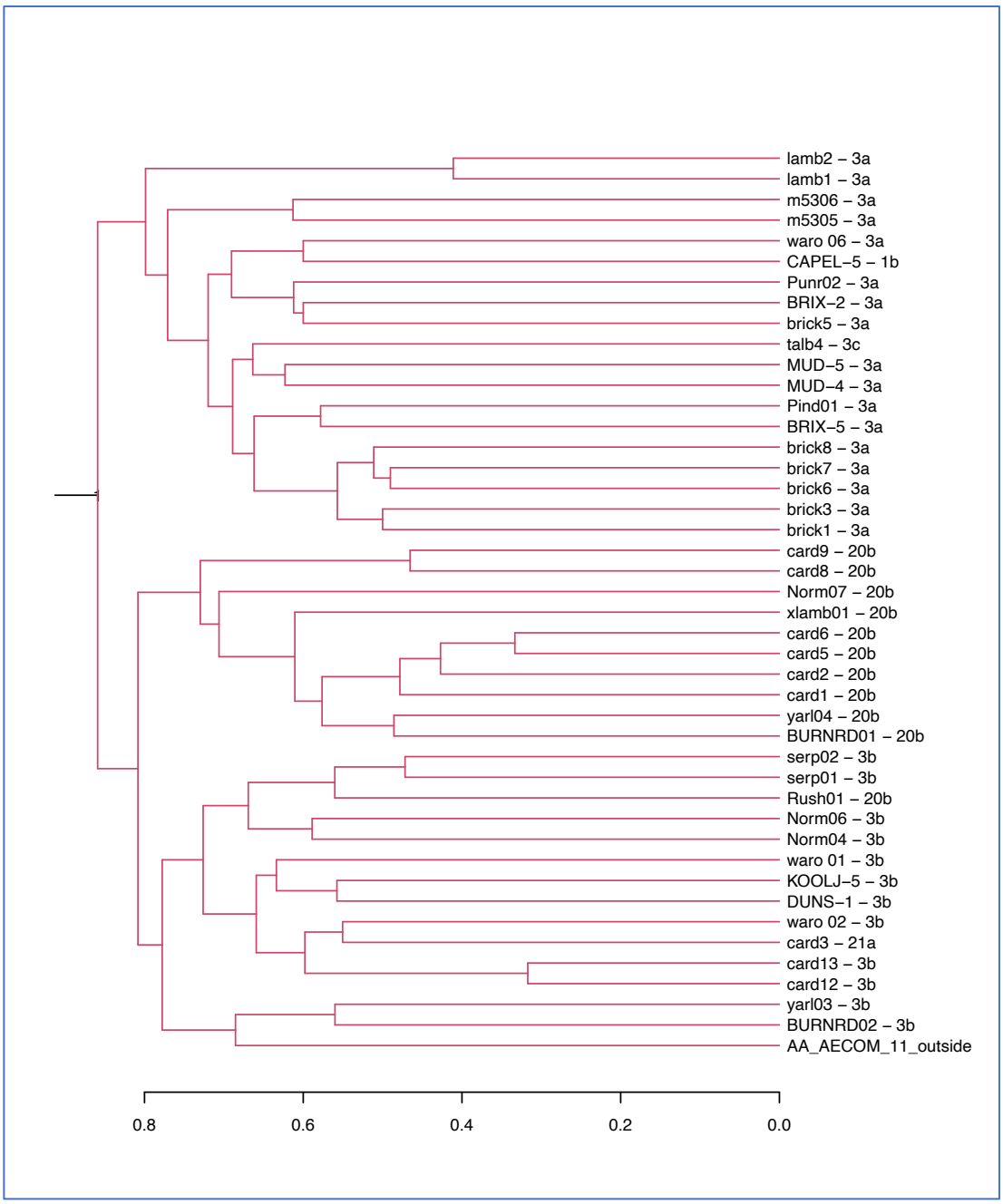

Figure 23: Partial dendrogram for the assignment of Plot AECOM_11 to the Keighery et al. (2012) floristic community types.

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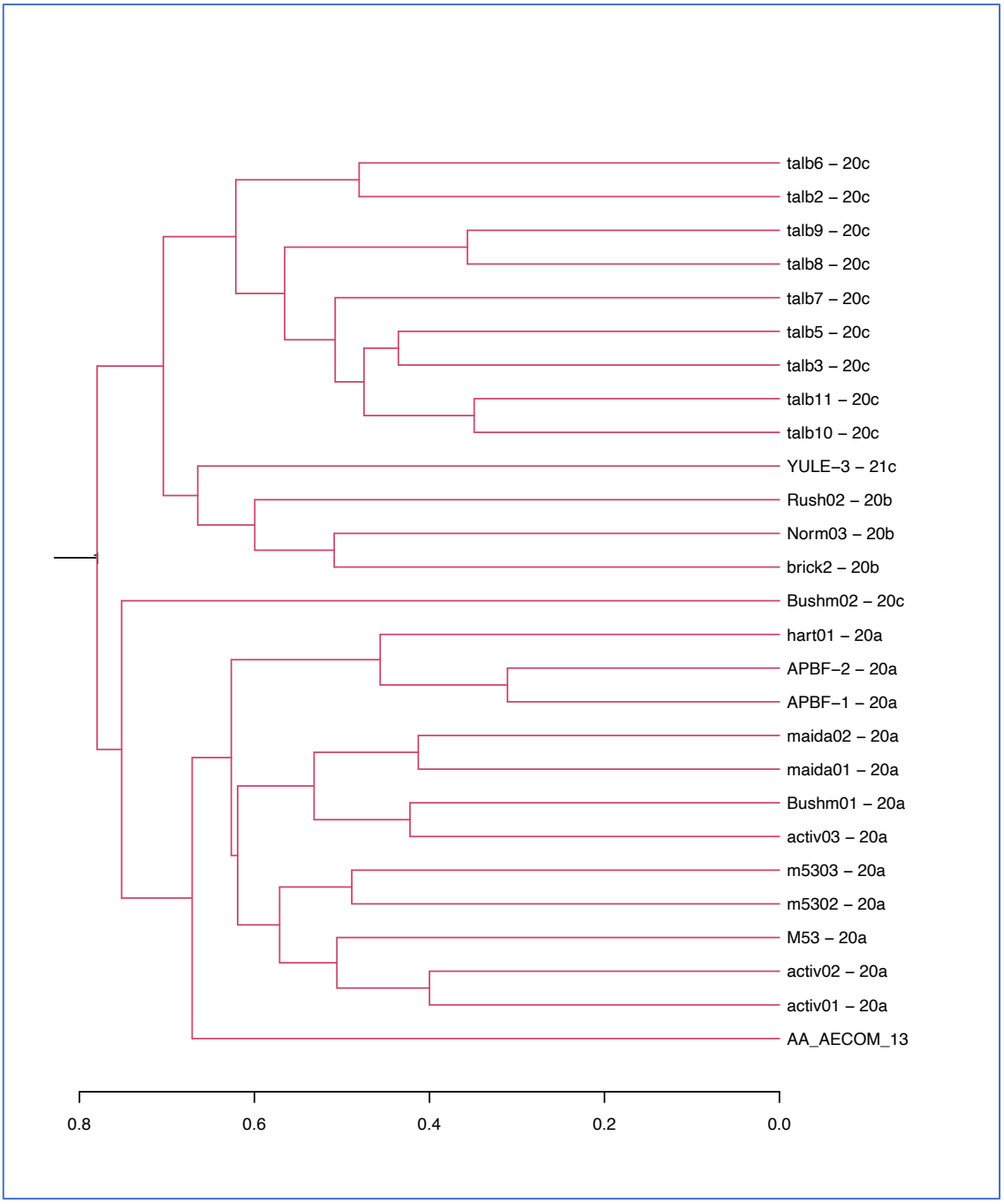

Figure 24: Partial dendrogram for the assignment of Plot AECOM_13 to the Keighery et al. (2012) floristic community types.

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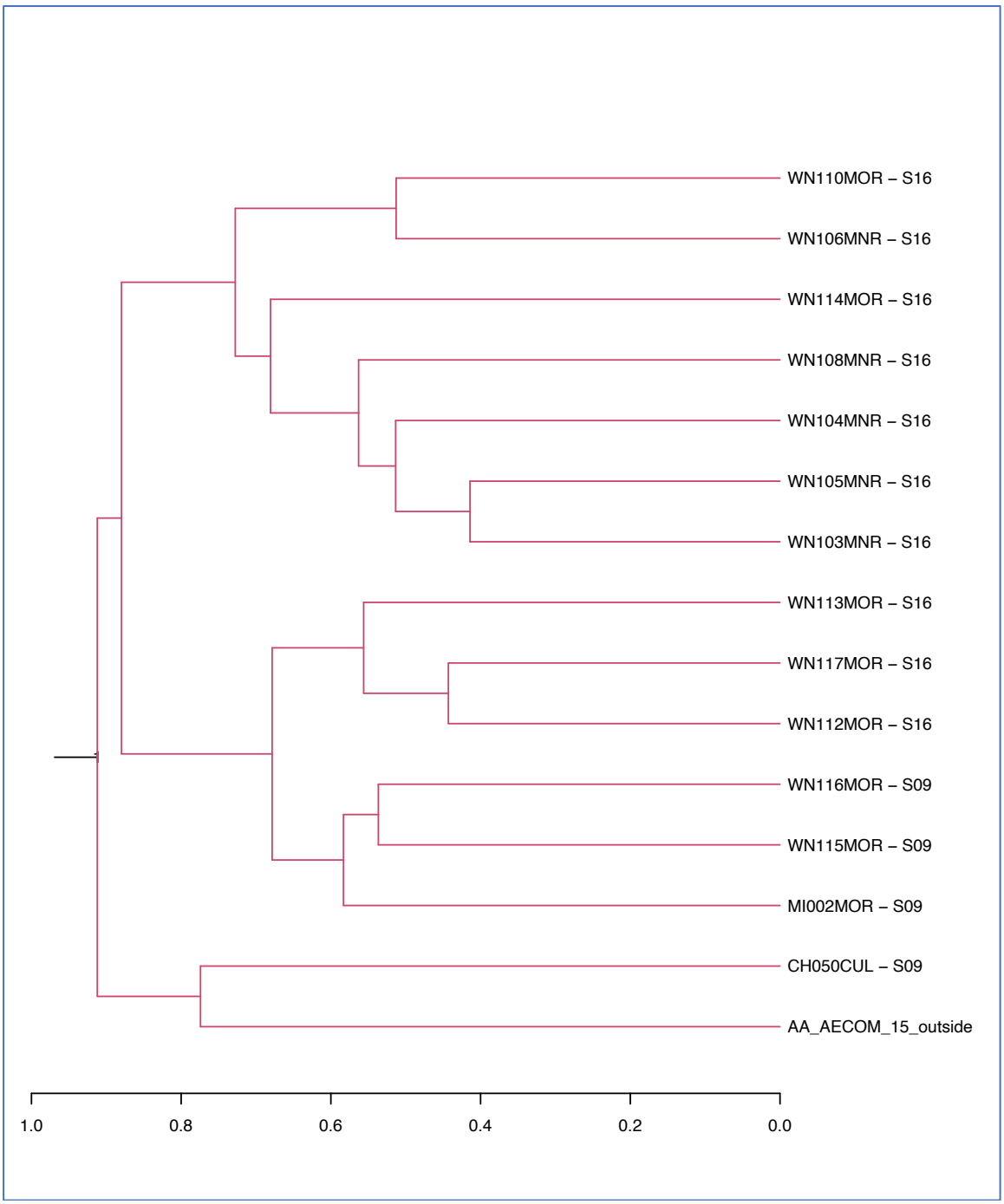

Figure 25: Partial dendrogram for the assignment of Plot AECOM_15 to the Keighery et al. (2012) floristic community types.

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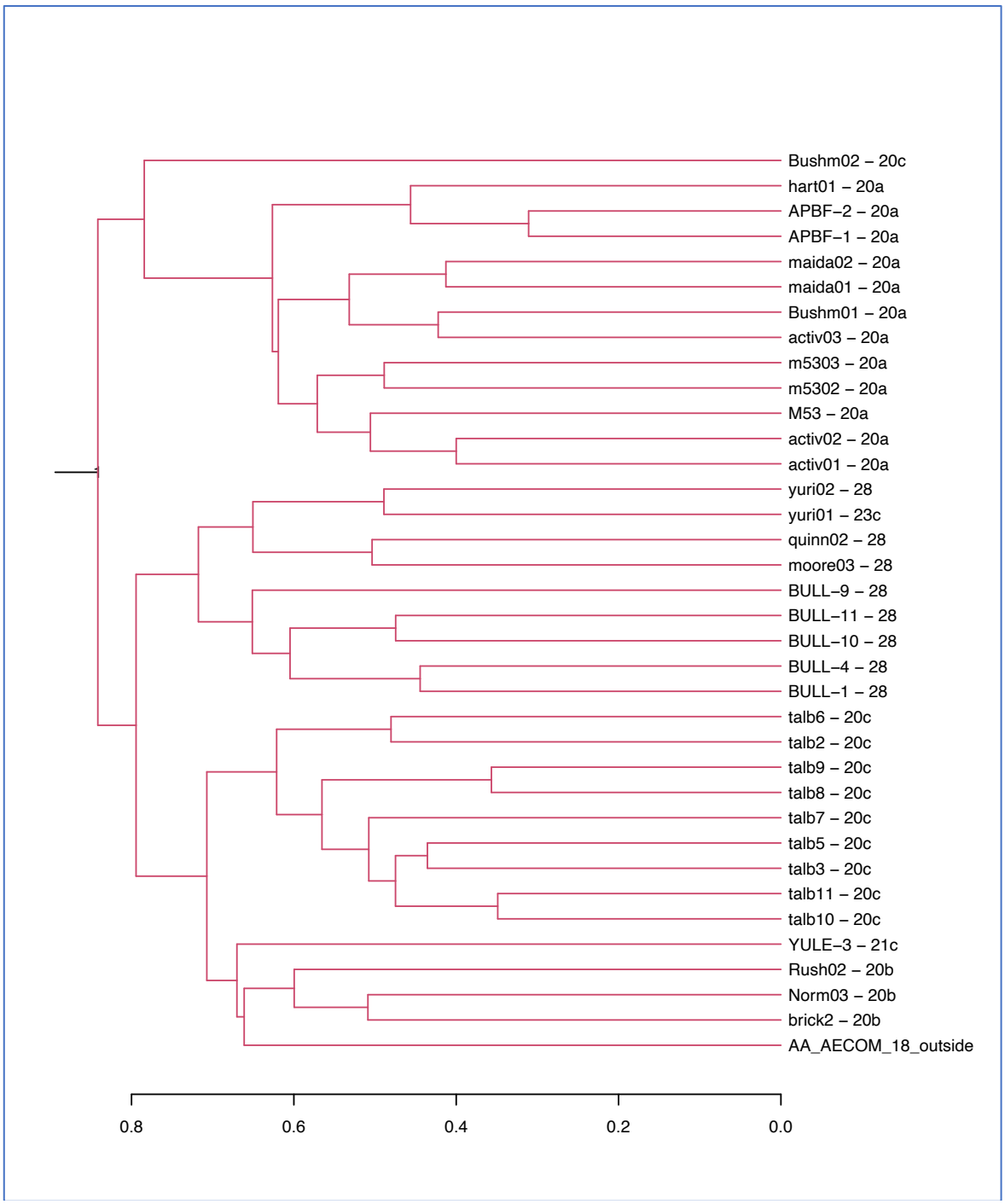

Figure 26: Partial dendrogram for the assignment of Plot AECOM_18 to the Keighery et al. (2012) floristic community types.

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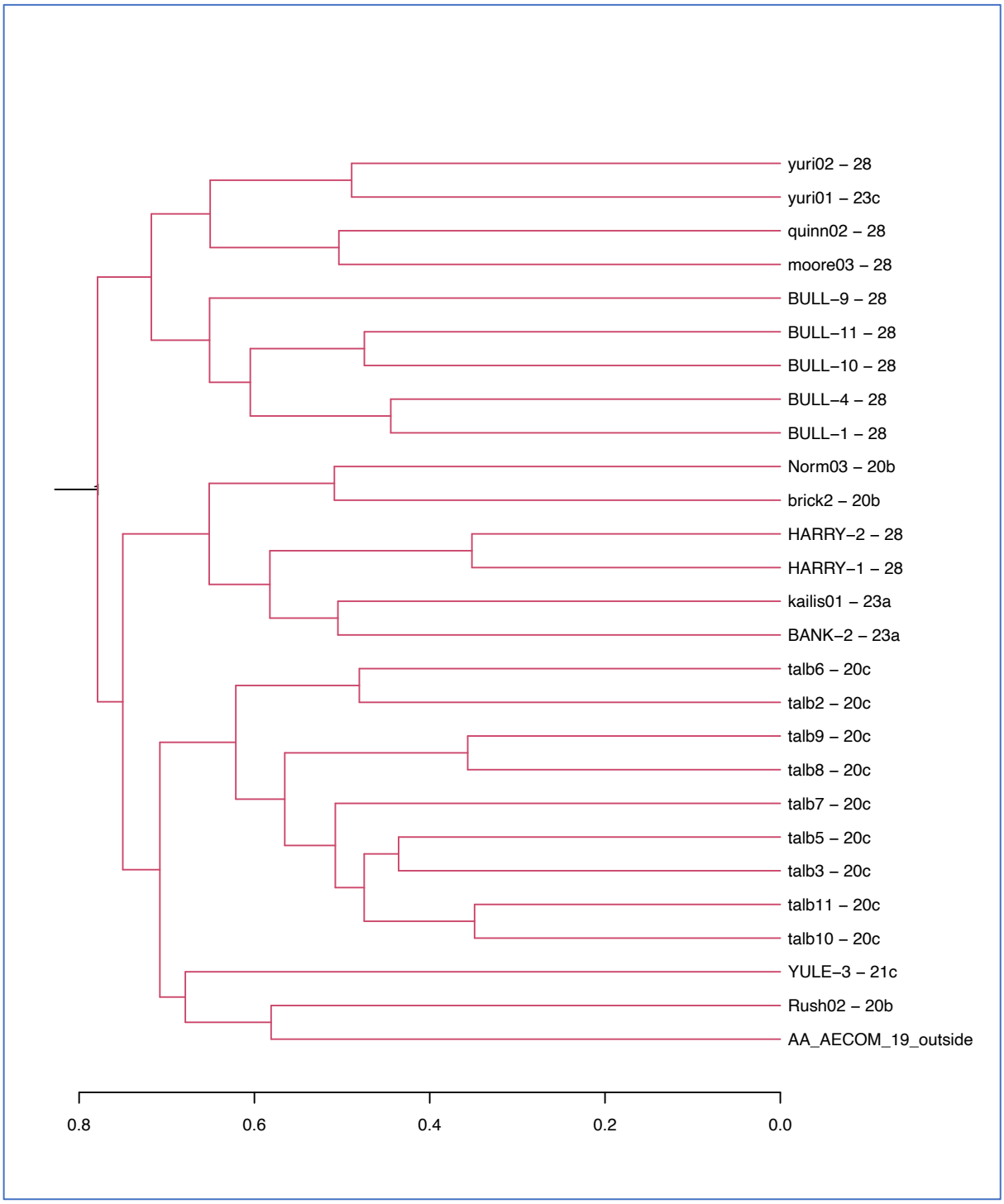

Figure 27: Partial dendrogram for the assignment of Plot AECOM_19 to the Keighery et al. (2012) floristic community types.

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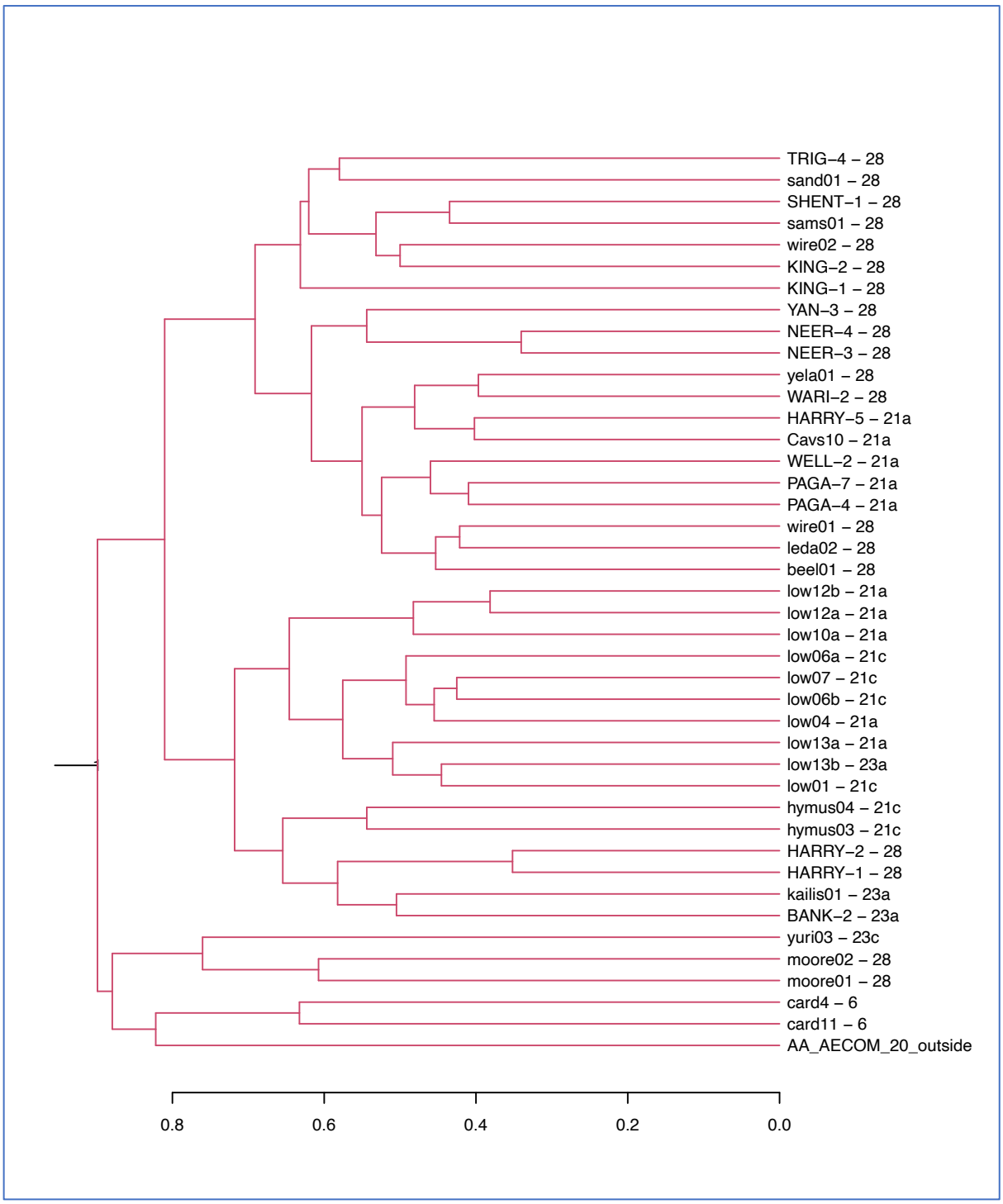

Figure 28: Partial dendrogram for the assignment of Plot AECOM_20 to the Keighery et al. (2012) floristic community types.

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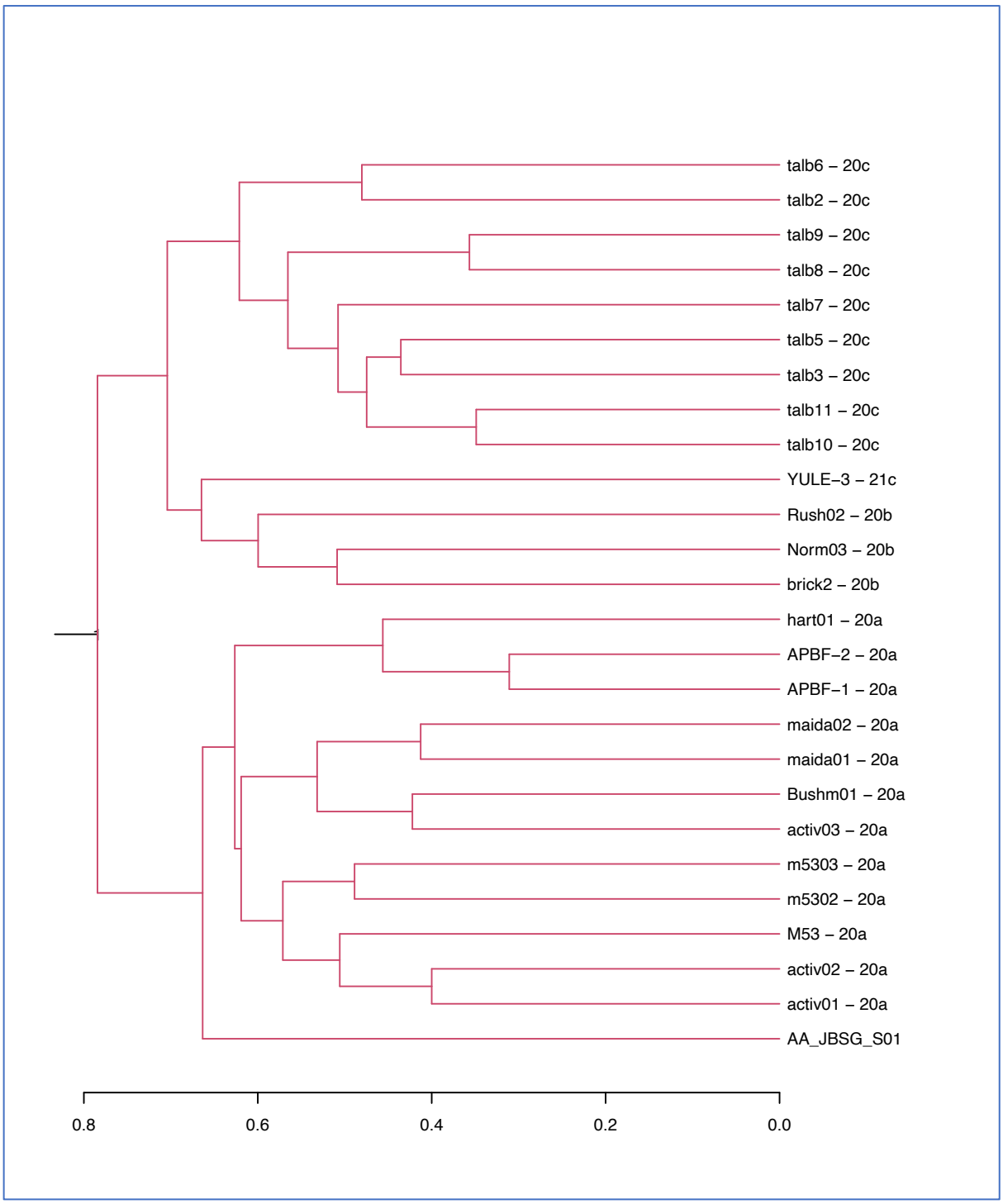

Figure 29: Partial dendrogram for the assignment of Plot AECOM_30 to the Keighery et al. (2012) floristic community types.

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Table 2: Bray Curtis dissimilarity values for Wattle Grove and the closest Swan Coastal Plain plots

Swan Coastal Plain Plot (FCT)	AECOM_11_outside	AECOM_15_outside	AECOM_20_outside	AECOM_7_outside	AECOM_1_outside	AECOM_13	AECOM_9	AECOM_10_outside	AECOM_6	AECOM_19_outside	AECOM_4	JBSG_S01	AECOM_18_outside
activ01-20a	0.855	0.813	0.770	0.940	0.845	0.575	0.704	0.901	0.593	0.670	0.621	0.563	0.745
activ02-20a	0.864	0.791	0.752	0.926	0.871	0.630	0.672	0.890	0.649	0.659	0.657	0.606	0.678
APBF-1-20a	0.772	0.856	0.778	0.885	0.783	0.618	0.768	0.848	0.638	0.714	0.676	0.642	0.772
APBF-2-20a	0.821	0.835	0.774	0.922	0.814	0.612	0.745	0.883	0.568	0.692	0.597	0.620	0.732
brick1-3a	0.808	0.861	0.832	0.894	0.800	0.818	0.824	0.853	0.812	0.835	0.810	0.841	0.846
brick2-20b	0.731	0.802	0.720	0.894	0.836	0.736	0.784	0.789	0.744	0.706	0.746	0.681	0.654
brick3-3a	0.849	0.825	0.817	0.917	0.875	0.805	0.808	0.897	0.782	0.784	0.813	0.791	0.811
brick6-3a	0.795	0.812	0.736	0.897	0.830	0.733	0.791	0.823	0.802	0.763	0.782	0.773	0.795
brick7-3a	0.783	0.775	0.789	0.854	0.816	0.853	0.822	0.880	0.771	0.794	0.807	0.822	0.848
brick8-3a	0.780	0.814	0.806	0.911	0.811	0.778	0.796	0.824	0.699	0.714	0.754	0.798	0.740
BURNRD01-20b	0.727	0.813	0.752	0.840	0.810	0.717	0.815	0.782	0.691	0.722	0.712	0.647	0.745
BURNRD02-3b	0.671	0.780	0.818	0.787	0.802	0.784	0.831	0.658	0.776	0.778	0.776	0.787	0.765
Bushm02-20c	0.915	0.882	0.838	0.934	0.922	0.705	0.710	0.903	0.667	0.763	0.720	0.800	0.746
card1-20b	0.706	0.778	0.771	0.826	0.722	0.714	0.800	0.785	0.687	0.701	0.710	0.694	0.667
card11-6	0.806	0.898	0.815	0.846	0.853	0.823	0.733	0.811	0.760	0.761	0.810	0.803	0.710
card12-3b	0.729	0.763	0.717	0.860	0.765	0.752	0.787	0.793	0.780	0.723	0.729	0.790	0.688
card13-3b	0.714	0.745	0.722	0.832	0.730	0.770	0.806	0.771	0.763	0.691	0.732	0.772	0.695
card2-20b	0.735	0.782	0.707	0.806	0.782	0.646	0.730	0.788	0.651	0.644	0.748	0.639	0.664
card4-6	0.877	0.806	0.794	0.964	0.859	0.854	0.714	0.821	0.769	0.771	0.839	0.865	0.692
card5-20b	0.733	0.824	0.685	0.895	0.748	0.689	0.748	0.792	0.661	0.655	0.701	0.649	0.657
card6-20b	0.750	0.849	0.778	0.860	0.804	0.752	0.787	0.839	0.725	0.762	0.763	0.676	0.729
CH050CUL-S09	0.969	0.774	0.853	0.891	0.944	0.878	0.810	0.929	0.821	0.800	0.885	0.865	0.785
DUNS-1-3b	0.792	0.786	0.798	0.896	0.821	0.805	0.846	0.794	0.815	0.766	0.828	0.791	0.755

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Swan Coastal Plain Plot (FCT)	AECOM_11_outside	AECOM_15_outside	AECOM_20_outside	AECOM_7_outside	AECOM_1_outside	AECOM_13	AECOM_9	AECOM_10_outside	AECOM_6	AECOM_19_outside	AECOM_4	JBSG_S01	AECOM_18_outside
Ellib01-S08	0.828	0.867	0.833	0.880	0.838	0.855	0.868	0.857	0.849	0.796	0.774	0.863	0.806
Ellib02-20d	0.848	0.789	0.805	0.884	0.859	0.833	0.844	0.857	0.804	0.738	0.723	0.795	0.772
GOLF-1-20a	0.859	0.833	0.706	0.933	0.810	0.690	0.670	0.867	0.643	0.712	0.702	0.648	0.737
hart01-20a	0.792	0.806	0.717	0.814	0.745	0.628	0.723	0.839	0.560	0.683	0.559	0.600	0.771
KOOLJ-5-3b	0.788	0.780	0.795	0.920	0.824	0.745	0.759	0.737	0.776	0.756	0.794	0.809	0.741
KOON-1-20a	0.810	0.765	0.722	0.853	0.802	0.574	0.670	0.854	0.678	0.636	0.717	0.544	0.657
KOON-2-20a	0.728	0.860	0.736	0.892	0.853	0.583	0.703	0.851	0.655	0.704	0.712	0.571	0.728
lamb1-3a	0.842	0.838	0.829	0.885	0.817	0.878	0.911	0.905	0.827	0.798	0.809	0.854	0.842
lamb2-3a	0.800	0.813	0.823	0.840	0.741	0.827	0.833	0.802	0.740	0.774	0.773	0.832	0.764
LAND-1-20a	0.818	0.776	0.735	0.880	0.810	0.606	0.722	0.822	0.642	0.635	0.667	0.597	0.655
M53-20a	0.794	0.808	0.745	0.897	0.876	0.694	0.733	0.878	0.667	0.679	0.736	0.655	0.701
m5302-20a	0.820	0.835	0.709	0.911	0.830	0.675	0.633	0.846	0.646	0.695	0.705	0.688	0.700
m5303-20a	0.820	0.833	0.772	0.921	0.846	0.625	0.706	0.863	0.581	0.707	0.624	0.633	0.730
maida01-20a	0.820	0.796	0.737	0.901	0.778	0.734	0.743	0.804	0.677	0.690	0.714	0.717	0.694
maida02-20a	0.806	0.800	0.792	0.904	0.838	0.691	0.802	0.810	0.679	0.673	0.704	0.725	0.656
MI002MOR-S09	0.942	0.909	0.889	1.000	0.893	0.860	0.821	0.967	0.854	0.865	0.846	0.872	0.855
moore01-28	0.860	0.835	0.864	0.956	0.887	0.897	0.816	0.824	0.858	0.886	0.852	0.908	0.840
moore02-28	0.859	0.854	0.818	0.893	0.890	0.863	0.759	0.868	0.796	0.844	0.776	0.894	0.835
Norm03-20b	0.750	0.812	0.736	0.846	0.809	0.695	0.744	0.797	0.703	0.656	0.673	0.629	0.659
Rush02-20b	0.800	0.814	0.709	0.889	0.811	0.641	0.735	0.868	0.628	0.581	0.574	0.651	0.640
Rush03-3b	0.686	0.838	0.771	0.848	0.796	0.832	0.800	0.828	0.809	0.794	0.758	0.838	0.804
serp03-3b	0.718	0.867	0.852	0.824	0.810	0.874	0.895	0.826	0.868	0.807	0.800	0.816	0.744
serp04-3b	0.718	0.878	0.864	0.787	0.780	0.863	0.855	0.816	0.837	0.756	0.813	0.830	0.765
talb10-20c	0.864	0.826	0.802	0.926	0.871	0.630	0.724	0.890	0.634	0.675	0.700	0.638	0.678

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talb11-20c	0.798	0.907	0.783	0.924	0.832	0.642	0.724	0.875	0.627	0.660	0.712	0.633	0.685
talb2-20c	0.778	0.719	0.717	0.888	0.821	0.716	0.739	0.796	0.692	0.672	0.741	0.746	0.658
talb3-20c	0.863	0.859	0.810	0.870	0.889	0.697	0.700	0.871	0.757	0.738	0.790	0.730	0.745
talb5-20c	0.880	0.814	0.786	0.933	0.868	0.744	0.673	0.868	0.735	0.733	0.721	0.743	0.720
talb6-20c	0.886	0.765	0.714	0.923	0.851	0.733	0.674	0.823	0.743	0.763	0.782	0.794	0.682
talb7-20c	0.859	0.805	0.727	0.893	0.868	0.706	0.614	0.895	0.714	0.667	0.738	0.702	0.671
talb8-20c	0.804	0.780	0.791	0.882	0.814	0.659	0.655	0.825	0.552	0.675	0.687	0.653	0.679
talb9-20c	0.798	0.774	0.696	0.899	0.826	0.619	0.664	0.800	0.574	0.632	0.695	0.661	0.651
waro01-3b	0.804	0.817	0.826	0.941	0.814	0.829	0.836	0.864	0.840	0.795	0.821	0.818	0.804
waro02-3b	0.678	0.791	0.752	0.833	0.823	0.733	0.793	0.761	0.756	0.724	0.786	0.748	0.695
WN112MOR-S16	0.950	0.896	0.880	0.943	0.884	0.835	0.846	0.944	0.806	0.835	0.765	0.865	0.850
WN113MOR-S16	0.943	0.910	0.863	0.967	0.947	0.885	0.912	0.967	0.904	0.840	0.848	0.848	0.886
WN115MOR-S09	0.973	0.886	0.921	0.873	0.899	0.800	0.803	0.969	0.860	0.872	0.811	0.878	0.863
WN116MOR-S09	0.977	0.905	0.889	0.948	0.914	0.808	0.859	1.000	0.840	0.826	0.817	0.854	0.862
WN117MOR-S16	0.948	0.919	0.900	0.881	0.928	0.936	0.920	1.000	0.911	0.878	0.818	0.930	0.896
yarl03-3b	0.677	0.778	0.771	0.831	0.758	0.764	0.846	0.667	0.792	0.755	0.774	0.804	0.742
yarl04-20b	0.759	0.810	0.802	0.837	0.789	0.760	0.830	0.798	0.736	0.735	0.769	0.761	0.759
YULE-3-21c	0.783	0.775	0.768	0.902	0.898	0.688	0.689	0.855	0.657	0.691	0.649	0.743	0.674
yuri03-23c	0.873	0.921	0.878	0.942	0.906	0.833	0.714	0.857	0.739	0.833	0.782	0.841	0.797
Minimum dissimilarity	**0.671**	**0.719**	**0.685**	**0.787**	**0.722**	**0.574**	**0.614**	**0.658**	**0.552**	**0.581**	**0.559**	**0.544**	**0.640**

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