DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

Native Vegetation Integrity Benchmarks

Technical details supporting Static Benchmarks
June 2019 (Version 1.2)

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Cover photo: Native vegetation, Wyrrabalong National Park. Ian Oliver/DPIE

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1. Introduction

This document focuses on the technical details supporting the Vegetation Integrity Benchmarks V1.2 uploaded to the BioNet Vegetation Classification application in June 2019. For differences between V1.2 and V1.1 benchmarks see the Release Notes.

2. Background

Benchmarks describe the reference state to which sites are compared to assess and score their site-scale biodiversity values. The three primary attributes of biodiversity; composition, structure and function (Noss 1990) can be described by benchmarks. When scores for composition, structure and function are combined into a vegetation integrity score, they provide the rigour and transparency needed to make site-scaled comparisons and inform natural resource management decision making tools such as the Biodiversity Assessment Method (BAM). The technical details that describe the data preparation, analyses and evaluations resulting in the delivery of V1.2 static benchmarks to BioNet and the BAM are provided below. For further information on the changes between V1.1 and V1.2 benchmarks, see the Release Notes.

3. Technical details

3.1 Data preparation – composition and structure

Composition and structure benchmarks were developed for the richness and summed species cover within six growth form groups (trees, shrubs, grass and grass-like, forbs, ferns, and growth forms not otherwise classified 'others'). This required that each of 7265 native species known to exist in New South Wales was first allocated to a primary growth form (that is, the most common growth form expressed by the species in its mature state across the extent of its range). An independent expert panel was used to make the species to growth form allocations and the process is documented in Oliver et al. (2019). Growth form descriptions and groupings are available in Oliver et al. (2019) and the BAM. All growth form allocations are available via the BAM Calculator.

Floristic inventories from more than 36000 full-floristic 0.04 hectare (ha) plots were used to create composition benchmarks (richness of native vascular plant species within growth form groups) and structure benchmarks (summed native vascular plant species cover among species within growth form groups). To meet the criteria for inclusion in this dataset, plots were screened and where possible remediated for: (i) allocation to Vegetation Class; (ii) true replicate (repeat survey of same site); (iii) census start and end date correct; (iv) full-floristics including exotic species recorded; (v) plot size (0.04 ha); (vi) spatial and temporal proximity; (vii) minimum quantitative cover entered into BioNet (0.1% or 1%); and (viii) species score method (quantitative cover (0-100%) or Braun-Blanquet cover-abundance (BBCA)). Full details of the data preparation and screening processes and the purpose-built BAM database containing the remediated floristic data are in Somerville et al. (2019).

Important note: All plots that met the above criteria were used regardless of condition state or past (but unknown) disturbance history.

Quantitative cover (0-100%) was estimated in only 6789 plot surveys in BioNet and was recorded on various BBCA scales for the remaining 29546 plot surveys. Because quantitative cover was required for all plot surveys (to generate summed species cover within growth forms) we used a regression model to estimate quantitative cover from BBCA data using a subset of the quantitative cover dataset, and then transformed all BBCA data to quantitative cover estimates accordingly. Full details on the modelling can be found in McNellie et al. (2019) and all BBCA scale transforms to quantitative cover are in Somerville et al. (2019).

Important note: The process of deriving summed native vascular plant species cover among species within growth form groups within a plot can result in cover estimates exceeding 100% due to species within growth form groups having overlapping foliage. The majority of observed summed cover values among all available plots were, however, < 100%.

3.2 Data preparation – function

Function data collected from 0.1 ha plots are used to calculate a vegetation integrity score in woody vegetation classes and include number of large trees; length of logs; litter cover; tree regeneration; and tree stem size diversity.

Large tree threshold sizes are required for the assessment of number of large trees (see Table 1). Threshold sizes were guided by models that predicted the probability of trees of differing size (diameter at breast height (dbh)) containing hollows. See Travers et al. (2018) for full details of the modelling.

Table 1 Large tree threshold size by Vegetation Class*

Vegetation Formation	Vegetation Class	Large Tree Threshold (dbh in cm)
Alpine complex	Alpine Bogs and Fens	N/A
	Alpine Heaths	
	Alpine Herbfields	
Arid shrublands (Acacia subformation)	Gibber Transition Shrublands	N/A
	North-west Plain Shrublands	
	Sand Plain Mulga Shrublands	
	Stony Desert Mulga Shrublands	
Arid shrublands (Chenopod subformation)	Aeolian Chenopod Shrublands	N/A
	Gibber Chenopod Shrublands	
	Riverine Chenopod Shrublands	
Dry sclerophyll forests (Shrub/grass subformation)	Central Gorge Dry Sclerophyll Forests	50
	Clarence Dry Sclerophyll Forests	50
	Cumberland Dry Sclerophyll Forests	50
	Hunter-Macleay Dry Sclerophyll Forests	50
	New England Dry Sclerophyll Forests	50
	Northern Gorge Dry Sclerophyll Forests	50
	North-west Slopes Dry Sclerophyll Woodlands	50
	Pilliga Outwash Dry Sclerophyll Forests	50
	Southern Hinterland Dry Sclerophyll Forests	50
	Upper Riverina Dry Sclerophyll Forests	50
Dry sclerophyll forests (Shrubby subformation)	Coastal Dune Dry Sclerophyll Forests	50
	North Coast Dry Sclerophyll Forests	50
	Northern Escarpment Dry Sclerophyll Forests	50
	Northern Tableland Dry Sclerophyll Forests	50
	South Coast Sands Dry Sclerophyll Forests	50
	South East Dry Sclerophyll Forests	50
	Southern Tableland Dry Sclerophyll Forests	50
	Southern Wattle Dry Sclerophyll Forests	50
	Sydney Coastal Dry Sclerophyll Forests	50
	Sydney Hinterland Dry Sclerophyll Forests	50
	Sydney Montane Dry Sclerophyll Forests	50
	Sydney Sand Flats Dry Sclerophyll Forests	50
	Western Slopes Dry Sclerophyll Forests	50
	Yetman Dry Sclerophyll Forests	50
Forested wetlands	Coastal Floodplain Wetlands	50
	Coastal Swamp Forests	50

Vegetation Formation	Vegetation Class	Large Tree Threshold (dbh in cm)
	Eastern Riverine Forests	50
	Inland Riverine Forests	50
Freshwater wetlands	Coastal Freshwater Lagoons	N/A
	Coastal Heath Swamps	
	Inland Floodplain Shrublands	
	Inland Floodplain Swamps	
	Montane Bogs and Fens	
	Montane Lakes	
Grasslands	Maritime Grasslands	N/A
	Riverine Plain Grasslands	
	Semi-arid Floodplain Grasslands	
	Temperate Montane Grasslands	
	Western Slopes Grasslands	
Grassy woodlands	Coastal Valley Grassy Woodlands	50
	Floodplain Transition Woodlands	50
	New England Grassy Woodlands	50
	Southern Tableland Grassy Woodlands	50
	Subalpine Woodlands	50
	Tableland Clay Grassy Woodlands	50
	Western Slopes Grassy Woodlands	50
Heathlands	Coastal Headland Heaths	N/A
	Northern Montane Heaths	30
	South Coast Heaths	N/A
	Southern Montane Heaths	N/A
	Sydney Coastal Heaths	30
	Sydney Montane Heaths	30
	Wallum Sand Heaths	30
Rainforests	Cool Temperate Rainforests	50
	Dry Rainforests	50
	Littoral Rainforests	50
	Northern Warm Temperate Rainforests	50
	Southern Warm Temperate Rainforests	50
	Subtropical Rainforests	50
	Western Vine Thickets	30**
Saline wetlands	Inland Saline Lakes	N/A
	Mangrove Swamps	
	Saltmarshes	
Semi-arid woodlands (Grassy subformation)	Brigalow Clay Plain Woodlands	30
	Inland Floodplain Woodlands	50
	North-west Floodplain Woodlands	30
	Riverine Plain Woodlands	30

Vegetation Formation	Vegetation Class	Large Tree Threshold (dbh in cm)
Semi-arid woodlands (Shrubby subformation)	Desert Woodlands	30
	Dune Mallee Woodlands	30
	Inland Rocky Hill Woodlands	30
	North-west Alluvial Sand Woodlands	30
	Riverine Sandhill Woodlands	30
	Sand Plain Mallee Woodlands	30
	Semi-arid Sand Plain Woodlands	30
	Subtropical Semi-arid Woodlands	30
	Western Peneplain Woodlands	30
Wet sclerophyll forests (Grassy subformation)	Montane Wet Sclerophyll Forests	80
	North Coast Wet Sclerophyll Forests	80
	Northern Escarpment Wet Sclerophyll Forests	80
	Northern Hinterland Wet Sclerophyll Forests	80
	Northern Tableland Wet Sclerophyll Forests	80
	South Coast Wet Sclerophyll Forests	80
	Southern Escarpment Wet Sclerophyll Forests	80
	Southern Lowland Wet Sclerophyll Forests	80
	Southern Tableland Wet Sclerophyll Forests	80

* from Capararo et al. (2019)

** Western Vine Thickets large tree threshold was set at 30 cm dbh based on expert knowledge

Note: Classes for which function assessment does not apply in the BAM are shown with N/A

Benchmarks are required for the function attributes number of large trees, length of logs and cover of litter. Prior to this project, the Systematic (Flora) Surveys data collection of BioNet Atlas held a collection of approximately 6700 plots from 141 surveys with data on length of logs, litter cover, and/or stem sizes. Few plots contained data for all three attributes. A data audit identified 44 datasets held by internal and external custodians that potentially contained new function attribute data. Acquisition, collation and screening of new function attribute data resulted in total numbers of useable 0.1 ha plots for function benchmark generation being 4367 for length of logs, 6971 for litter cover, and 2302 for number of large trees. Where data were from sites that were obviously highly modified (e.g. following forest thinning trials) data were excluded. Full details of the data audit, acquisition, collation, screening and preparation processes are provided in Capararo et al. (2019).

3.3 Data analyses – composition and structure

All available plots were analysed using multivariate, hierarchical Bayesian methods that took account of differences among vegetation formations, vegetation classes, bioregions, seasons (month), recent rainfall (past 12 months) and exotic cover. Full details of the modelling and benchmark estimation are available in Yen et al. (2019).

Composition benchmarks (richness of native vascular plant species within growth form groups) and structure benchmarks (summed native vascular plant species cover among species within growth form groups) were estimated for 1710 regional vegetation classes (RVCs). RVCs are an amalgamation of Interim Biogeographic Regionalisation of Australia (IBRA) Bioregions (version 7; Thackway & Cresswell 1995) and Vegetation Classes (Keith 2004). Of the 1710 theoretical combinations of Bioregion (18 represented) and Vegetation

Class (95 represented), plot data were available for 469 combinations. Many of the unobserved combinations do not exist and are unlikely to exist under current climatic conditions (e.g. Subtropical Rainforests in the Australian Alps Bioregion). However, benchmarks were estimated for all combinations to cater for approximately 200 expected real, but un-sampled RVCs.

Important note: Where numbers of plots within an RVC were low, modelling of benchmark estimates used information from plots in the same Vegetation Class but different Bioregions, and to a lesser extent, information from plots in the same Bioregion but different Classes.

Both static and dynamic benchmarks were estimated for each RVC. However, at the time of writing, dynamic benchmarks were still undergoing evaluation. They will be added to the BioNet Vegetation Classification application as part of future updates.

Static benchmarks assumed average past rainfall and provided an estimated average value across survey months. This approach resulted in 1710 static species richness and cover benchmarks for each growth from group (20520 in total).

Dynamic benchmarks estimated values for each survey month for each of three prior 12-month rainfall totals (dry < 10^{th}, average 10^{th} – 90^{th}, wet > 90^{th} long-term percentiles). This approach resulted in 20520 dynamic species richness and cover benchmarks for each growth form group and rainfall level (738720 in total).

Static and dynamic benchmarks were broadly similar in many cases. However, the effects of season and past rainfall differed among vegetation classes and bioregions, and were most pronounced in forbs (Figure 1). For example, forb richness and forb cover peaked in spring in southern and central bioregions (e.g. Riverina bioregion, Figure 1a,b) but in summer in northern bioregions (e.g. Brigalow Belt South, see Yen et al. 2019). In drier bioregions, forb richness and forb cover often had no clear seasonal trend but were associated strongly with total rainfall over the 12 months prior to a given survey (e.g. Nandewar bioregion, Figure 1c,d). Vegetation in coastal bioregions often had weak associations with season and rainfall (e.g. coastal vegetation classes in the Sydney Basin bioregion, Figure 1e,f).

Important note: Failing to account for variation due to recent rainfall and season could result in the use of (static) benchmarks that are either unattainable or too-readily attainable, which may lead to undesirable biodiversity outcomes. When available, the use of dynamic benchmarks is encouraged especially when seasonal or climatic effects on growth form richness and cover are expected.

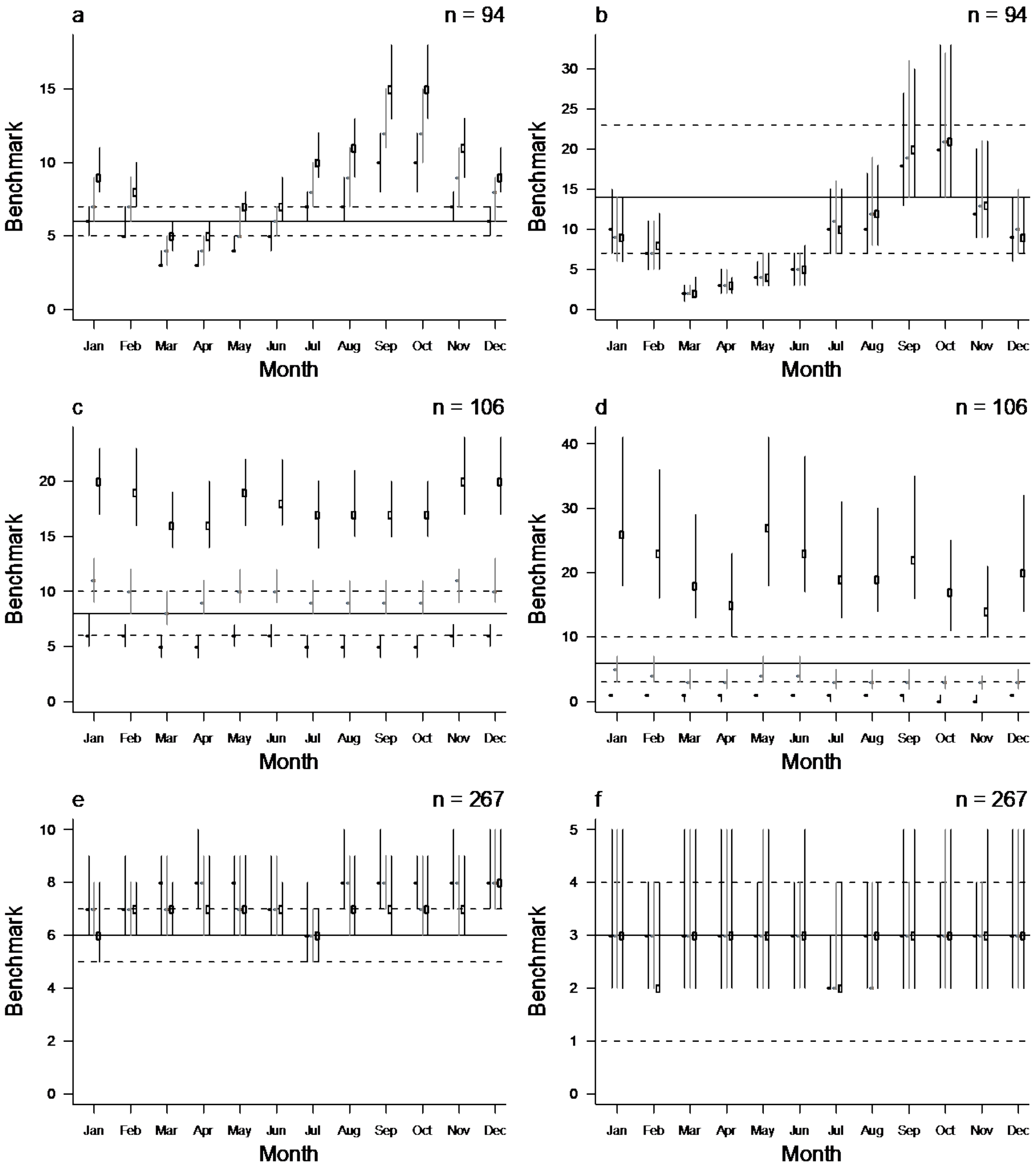

Figure 1 **Estimated benchmarks for forb richness (left-hand column) and forb cover (right-hand column)***

* Horizontal lines are **static benchmarks** based on 65th percentiles (solid lines) bounded by 55th and 75th percentiles (dashed lines). Points are **dynamic benchmarks** at three different rainfall levels: dry (solid black points), average (solid grey points), and wet (open points). Points are 65th percentiles and vertical bars extend from 55th to 75th percentiles. The number of plots (n) in each RVC are in the top-right corner (a,b Riverina, Floodplain Transition Woodlands; c,d Nandewar, Northern Tableland Dry Sclerophyll Forests; e,f Sydney Basin, Coastal Floodplain Wetlands) (reproduced from Yen et al. 2019).

3.4 Data analyses – function

The benchmark generation process for composition and structure attributes contained sufficient numbers of data points such that sophisticated modelling could be used, and benchmarks could be estimated for RVCs with few or no site data. Function attributes had many fewer data and modelling has not been attempted. An alternative 'hierarchical' approach was designed to allow attribution of benchmark values based on raw data distributions to each RVC even when there were insufficient data at this level.

At least 30 data points were required to generate the benchmark values at the RVC level. RVCs with fewer than 30 data points inherited benchmark values from calculations at the Vegetation Class level, regardless of Bioregion. If the Vegetation Class had fewer than 30 data points, amalgamated data from the relevant combination of Formation by Bioregion was used. Where there were fewer than 30 data points at the Formation by Bioregion level, amalgamated data from the corresponding Formation was used. Using this hierarchical approach, it was possible to generate function benchmark values that could be applied to all RVCs. The threshold of 30 data points was determined based on bootstrapping analyses from RVCs that had more than 50 data points. For full details of these analyses see Appendix III in Capararo et al. (2019).

Using the above approaches, function benchmarks were generated at a variety of classification levels (up to Formation) and represented the 75th percentile of each attribute's raw data distribution. The benchmark values and classification level applicable to each function attribute for each RVC are available in the BioNet Vegetation Classification application. Full details of the BAM Function Analysis Database are in Capararo et al. (2019).

3.5 Benchmark evaluation – composition and structure

Important note: Analyses assumed that available plot data used to estimate composition and structure benchmarks sampled the full range of condition and disturbance states. However, many of the plots were from relatively intact native vegetation (most growth form groups commonly associated with each RVC were present at most plots in that RVC). Therefore, although plots represented a range of condition states and disturbance histories, there was a degree of bias towards less disturbed or better condition plots in the dataset.

Yen et al. (2019) estimated composition and structure benchmarks at a range of levels from low (50th percentile (median), to high 85th percentile) and suggested 'if there is a sampling bias towards relatively undisturbed (or disturbed) vegetation, a lower (or higher) percentile [benchmark] may be appropriate'. For example, if all data were from long-undisturbed high condition plots replete with species, function attributes and structural complexity (relative to the same vegetation type and bioregion), the 50th percentile (median of the data distribution) may be an appropriate benchmark level. Alternatively, if all data were from heavily disturbed poor condition plots lacking species, function attributes and structural complexity (relative to the same vegetation type and bioregion), the 85th or higher may be appropriate. Cognisant that many of the available plots fell between these two extremes the benchmark target level was set at the 75th percentile for both richness and cover.

Evaluation of the target 75th percentile was then based on:

1. the relationship between estimated percentiles and the 75th percentile from observed data,

2. the stability of the above relationships with varying numbers of plots within RVCs.

Composition (richness)

A strong relationship was revealed between growth form richness at the observed 75th and estimated 75th percentiles with slope values close to 1 and R^2 values generally > 0.9 for all growth forms. These relationships were independent of the number of plots in an RVC (Appendix 1).

Evaluation of the estimated composition (richness) benchmarks, therefore, supported the use of the 75th percentile as the estimated growth form richness benchmark for use in the BAM (Table 2).

Table 2 Recommended estimated percentiles for richness benchmarks for the BAM

Growth form	BAM Richness percentile
Ferns	75th
Forbs	75th
Grass & grass-like	75th
Others	75th
Shrubs	75th
Trees	75th

Important note: Evaluation provided a **high level of confidence** in estimated growth form richness benchmarks regardless of the number of available plots within an RVC. The use of local growth form richness benchmarks is therefore **not** encouraged.

Structure (cover)

The distributions of observed growth form cover data revealed some summed cover values much greater than 100% (Vegetation Condition Benchmarks Cover and Richness raw data V1.2). Although summed species cover values greater than 100% are to be expected, very high values are questionable and may simply reflect poor field practices. Estimated (modelled) 75th percentiles also resulted in outliers much greater than 100% cover for grasses, trees and shrubs, or approaching 100% for remaining growth forms.

Unexpectedly high cover benchmarks are undesirable as they may not meet assessor expectations and will lead to unwarranted dominance of a single growth form (due to dynamic weighting; see OEH 2018) in the calculation of the BAM structure score. To guard against the undesirable effects of outliers, estimated cover benchmarks were manually capped at the maximum 75th percentile observed from RVCs with 20 or more plots (Table 3). This process ensured that estimated benchmarks fell within the global range of 75th percentile values observed within RVCs with > 20 plots.

Evaluation of the estimated cover percentiles (including capped values) against the observed (target) 75th cover percentiles was then based on:

1. the relationship between estimated percentiles and the 75th percentile from observed data,
2. the stability of the above relationships with varying numbers of plots within RVCs.

Table 3 **Maximum 75th percentile observed from raw data from RVCs with 20 or more plots used to cap cover benchmark estimates**

Growth form	Observed 75th maximum foliage cover (%)
Ferns	56
Forbs	22
Grass & grass-like	102
Others	48
Shrubs	113
Trees	171

Table 4 and Appendix 2 revealed that for all growth forms except grass & grass-like, slope values closest to 1 were for estimated benchmarks less than the observed (target) 75th. These relationships guided the selection of cover benchmark percentiles for use in the BAM (Table 5). Additional support for these percentiles was also derived from the consideration of root mean squared deviation (RMSD, Appendix 3) which measures the deviation of observed versus estimated values against the 1:1 line shown on plots in Appendix 2. For all growth forms, RMSD was lowest for the selected percentiles (Appendix 3).

Table 4 **Relationship between observed 75th and estimated percentiles for cover**

Growth form	Slope					
	Estimated percentile	**60th**	**65th**	**70th**	**75th**	**80th**
Ferns	>0 plots	2.09	1.40	0.90	0.61	0.45
	>20 plots	2.14	1.42	0.94	0.61	0.45
	>50 plots	1.88	1.26	0.82	0.52	0.38
	>100 plots	1.84	1.23	0.80	0.51	0.36
	>200 plots	2.08	1.39	0.91	0.56	0.34
Forbs	>0 plots	2.10	1.68	1.33	1.05	0.82
	>20 plots	1.73	1.39	1.11	0.87	0.67
	>50 plots	1.65	1.33	1.07	0.84	0.64
	>100 plots	1.58	1.28	1.02	0.80	0.61
	>200 plots	1.55	1.24	1.00	0.78	0.60
Grasses	>0 plots	1.50	1.23	1.02	0.85	0.72
	>20 plots	1.65	1.31	1.08	0.89	0.74
	>50 plots	1.84	1.45	1.16	0.93	0.75
	>100 plots	1.85	1.46	1.18	0.93	0.74
	>200 plots	1.99	1.56	1.21	0.92	0.71

Growth form		Slope				
Others	>0 plots	1.47	1.04	0.76	0.59	0.48
	>20 plots	1.24	0.88	0.64	0.49	0.40
	>50 plots	1.31	0.93	0.68	0.51	0.40
	>100 plots	1.28	0.91	0.67	0.51	0.39
	>200 plots	1.26	0.90	0.63	0.44	0.33
Shrubs	>0 plots	1.06	0.84	0.67	0.55	0.46
	>20 plots	1.21	0.96	0.78	0.66	0.54
	>50 plots	1.26	1.00	0.80	0.65	0.52
	>100 plots	1.33	1.01	0.77	0.63	0.51
	>200 plots	1.30	0.98	0.75	0.61	0.50
Trees	>0 plots	0.82	0.66	0.53	0.42	0.35
	>20 plots	0.94	0.73	0.58	0.45	0.37
	>50 plots	0.98	0.76	0.60	0.46	0.38
	>100 plots	0.97	0.76	0.60	0.47	0.38
	>200 plots	0.95	0.73	0.57	0.44	0.36

Table 5 Recommended estimated percentiles for summed cover benchmarks for the BAM

Growth form	BAM Cover percentile
Ferns	70th
Forbs	70th
Grass and Grass-like	75th
Others	65th
Shrubs	65th
Trees	60th

The use of estimated benchmark percentiles lower than the 75th to represent the observed (target) 75th percentile was supported by the findings of Yen et al. (2019). They found that fitted models explained considerably less variation in cover than for richness and that ‘small sample sizes and large amounts of residual variation potentially inflated benchmarks, and this variability increased from lower to higher percentiles, which might suggest that a lower percentile is appropriate when few data are available or when residual variation is high’.

Unexplained variation in cover data across all growth forms is likely due to imprecision and variability among assessors in visual estimates of cover as well as variable class based (Braun-Blanquet) cover assessment methods. A further source of unexplained variation is likely to have resulted from the use of multiple methods for measuring tree/canopy cover.

Yen et al. (2019) included the method of tree cover assessment where known (crown cover, foliage cover, projected foliage cover) as a covariate in preliminary models. However, it did not improve the model fit so was not included in final models. Nevertheless, the inclusion of variable types of tree cover data in the dataset is likely to have increased unexplained variation and resulted in the model on average overestimating tree cover and therefore resulting in the best fit with the observed 75th percentile being the estimated 60th percentile.

Although a slope of 1 means that on average observed 75th percentiles equalled the chosen estimated percentiles, variability around this relationship, or the scatter of points around the 1:1 line, can be considerable (Appendix 2). With a slope of 1, a similar number of benchmarks are overestimated as are underestimated. The magnitude of over- and underestimates is represented by root mean squared deviation (RMSD, Appendix 3), with smaller RMSD values meaning smaller over- and underestimates compared to observed values. RMSD is therefore a useful measure of benchmark confidence.

For all growth forms, variability in cover estimates was highest (highest RMSD) when plot numbers within RVCs were lowest (Appendix 3). Relationships were poorest when RVCs with < 20 plots were included but improved appreciably when analyses included RVCs with > 20 plots. Relationships improved incrementally with higher plot numbers (Appendix 3).

Based on these relationships and higher unexplained variation in cover models, confidence ratings were limited to Low for RVCs with < 20 plots and Moderate for RVCs with ≥ 20 plots (Table 6). Confidence ratings should be used to guide when locally generated benchmarks may be more appropriate (Table 6).

Table 6 Confidence in cover benchmarks and recommendations for use of local cover benchmarks

Confidence	Number of plots per RVC	Recommendation
Low	< 20	local **cover** benchmarks **should be** considered
Moderate	≥ 20	local **cover** benchmarks **may be** considered

Finally, reassessment of the summed cover benchmark caps that were applied prior to the above evaluation processes (Table 3) revealed that approximately 94% of the RVCs affected were RVCs with low benchmark confidence (Table 7). Many of these RVCs are unlikely to exist under current climatic conditions (e.g. Subtropical Rainforests in the Australian Alps Bioregion). Only 19 RVCs with moderate confidence (≥ 20 plots) had their benchmarks capped, with the majority of these being grass & grass-like benchmarks.

Table 7 **Numbers of cover benchmark values capped at Table 3 maxima and the number of RVCs affected by capping**

	Number of Static Cover Benchmarks capped with		
Growth form	**Moderate confidence**	**Low confidence**	**Total**
Ferns	0	3	3
Forbs	0	41	41
Grass and Grass-like	15	208	223
Others	0	3	3
Shrubs	5	58	63
Trees	0	19	19
RVCs Affected	**19**	**306**	**325**

Important note: Cover assessment for all growth forms was assumed to be foliage cover and estimated cover benchmarks are for foliage cover (leaves and branches, etc.).

3.6 Benchmark evaluation – function

Function benchmarks for length of logs and cover of litter were the observed 75th percentile. No further evaluation was undertaken.

Function benchmarks for number of large trees were guided by Travers et al. (2018) however large tree thresholds suggested by Travers et al. (2018) were evaluated against resultant number of large tree benchmark values given available data. Where a threshold resulted in a number of large trees benchmark < 1, the size threshold was reduced. In contrast, where a threshold resulted in a number of large trees threshold > 10, it was increased.

A confidence level was attributed to each function benchmark, based on: (i) the level in the vegetation type classification hierarchy at which benchmark values were calculated, and (ii) the number of records from which the benchmark values were generated. The accuracy of benchmark values was assumed to increase as the classification becomes finer (from Formation to Class x Bioregion (RVC)) and the number of plots becomes greater (Table 8).

Where function benchmarks are at moderate or lower confidence, local function benchmarks are encouraged. Investment in the collection of new function attribute data is strongly encouraged across all vegetation field programs due to the paucity of these data.

Table 8 Confidence matrix as applied to function benchmarks for the number of large trees, length of logs and cover of litter

Number of records	Formation	Formation X Bioregion	Class	Class X Bioregion
< 30	Very low	N/A	N/A	N/A
30 – 99	Low	Low	Moderate	High
100 – 200	Low	Moderate	High	High
>200	Moderate	High	High	Very high

4. Future work

Where RVC benchmarks are represented by few plots, confidence in benchmark values may be low. Gap-filling vegetation survey work currently underway will provide new data to improve models and confidence ratings for composition and structure. However, as stated above, investment in the collection of new function attribute data is strongly encouraged across all vegetation field programs due to the relative paucity of such data and consequent lower levels of confidence in function benchmark estimates. Modelling of function benchmarks is however worthy of further consideration.

The project team has also investigated the potential to deliver composition and structure benchmarks at a finer level of classification, namely Class x IBRA sub-region, and at the Plant Community Type (PCT) level (Watson et al. 2018). The overall findings of this work were that while there may be benefit in generating fine-scale benchmarks for targeted vegetation types, current availability of plot allocation and floristic data will hamper the practicalities of generating fine-scale benchmarks at either the PCT or the IBRA sub-regional scale.

As new vegetation data become available, and new analyses are undertaken to deliver improved benchmarks, periodic benchmark uploads will be undertaken and communicated.

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6. Appendices

Appendix 1 – Evaluation of composition benchmarks:

Plots of estimated species richness benchmarks (from 50th to 85th percentile) against observed 75th percentiles for each Regional Vegetation Class (RVC) (dashed lines show 1:1 relationship)

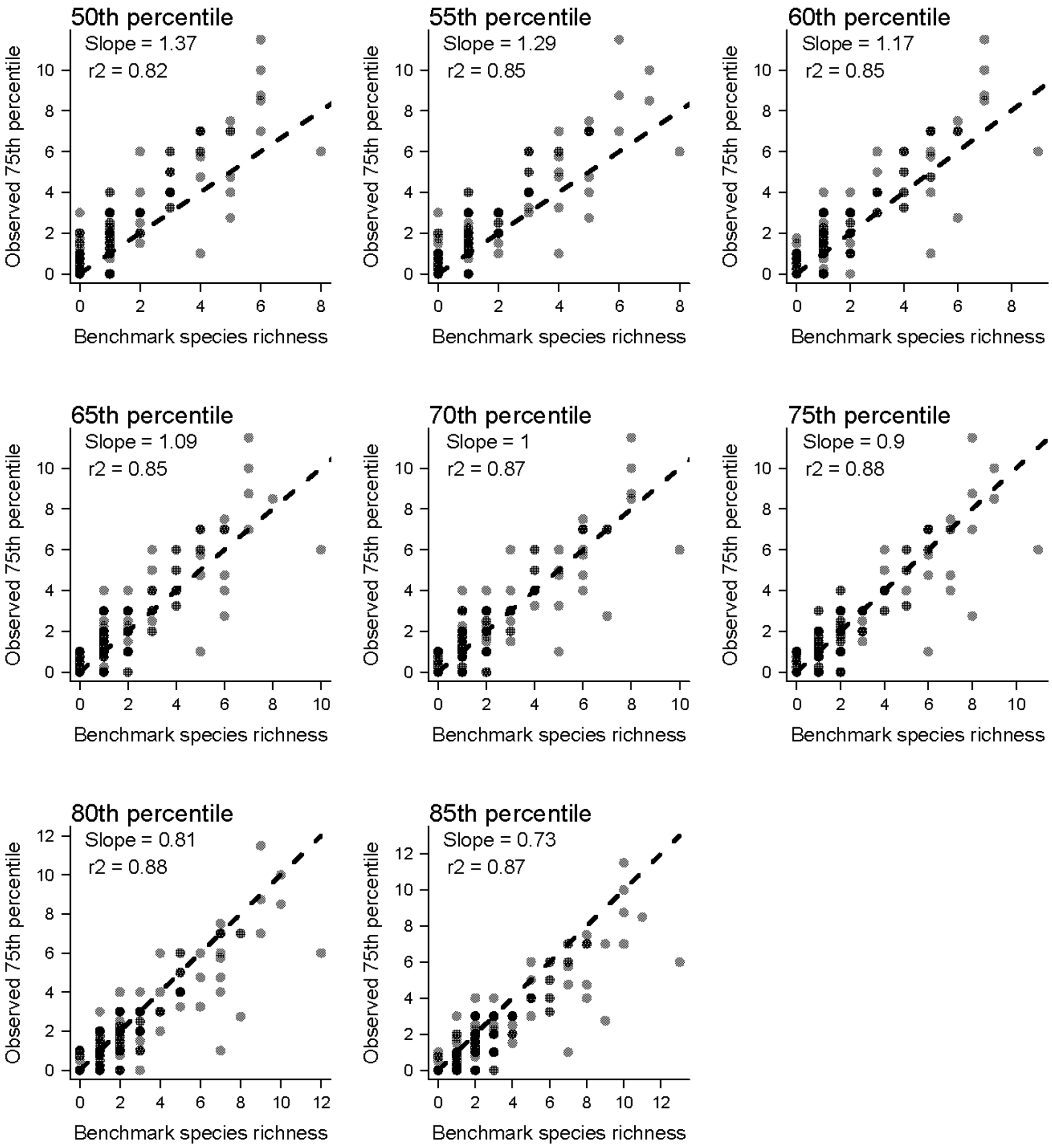

Figure 2 **Estimated versus observed fern richness percentiles for RVCs with > 0 plots**

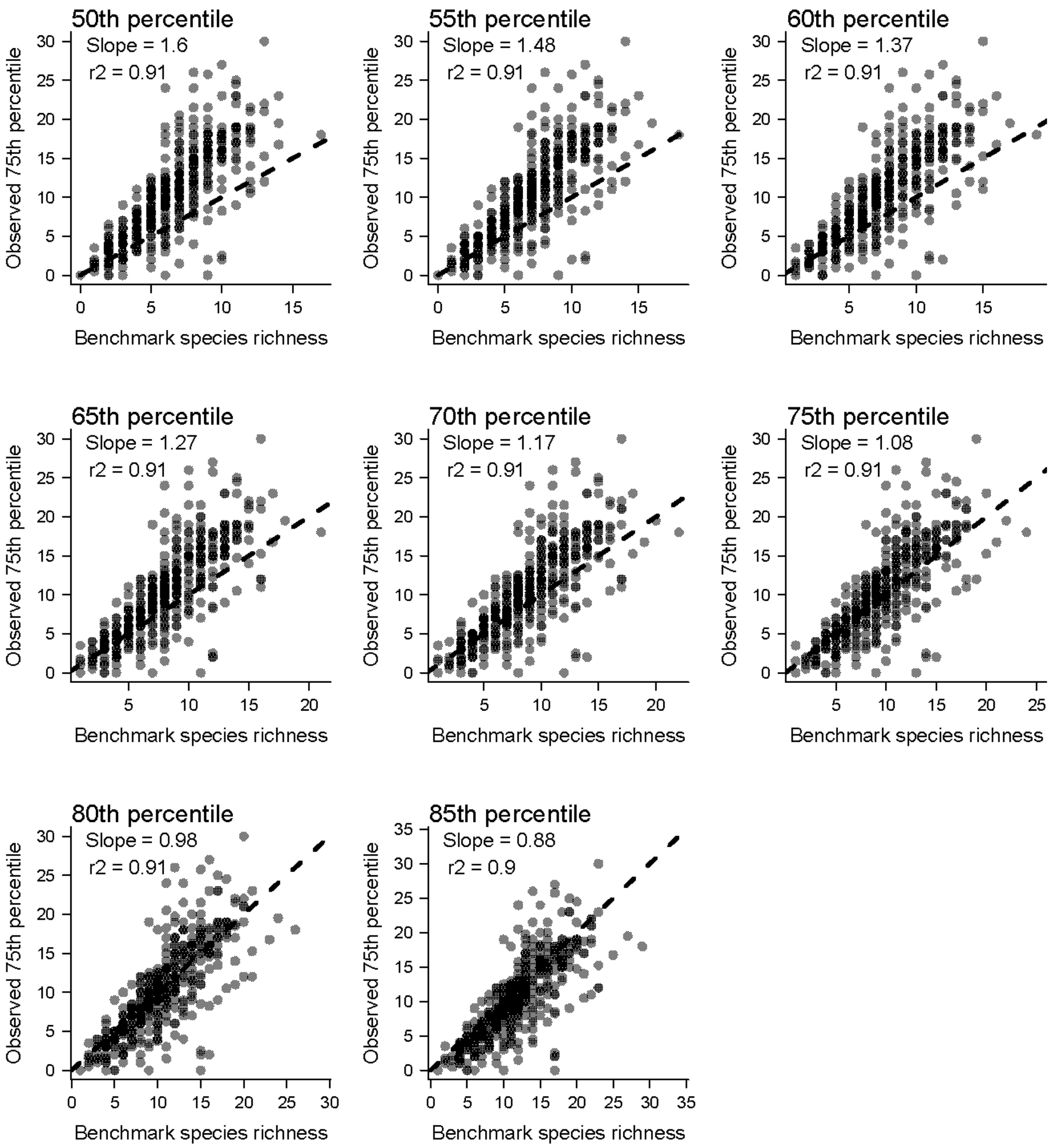

Figure 3 Estimated versus observed forb richness percentiles for RVCs with > 0 plots

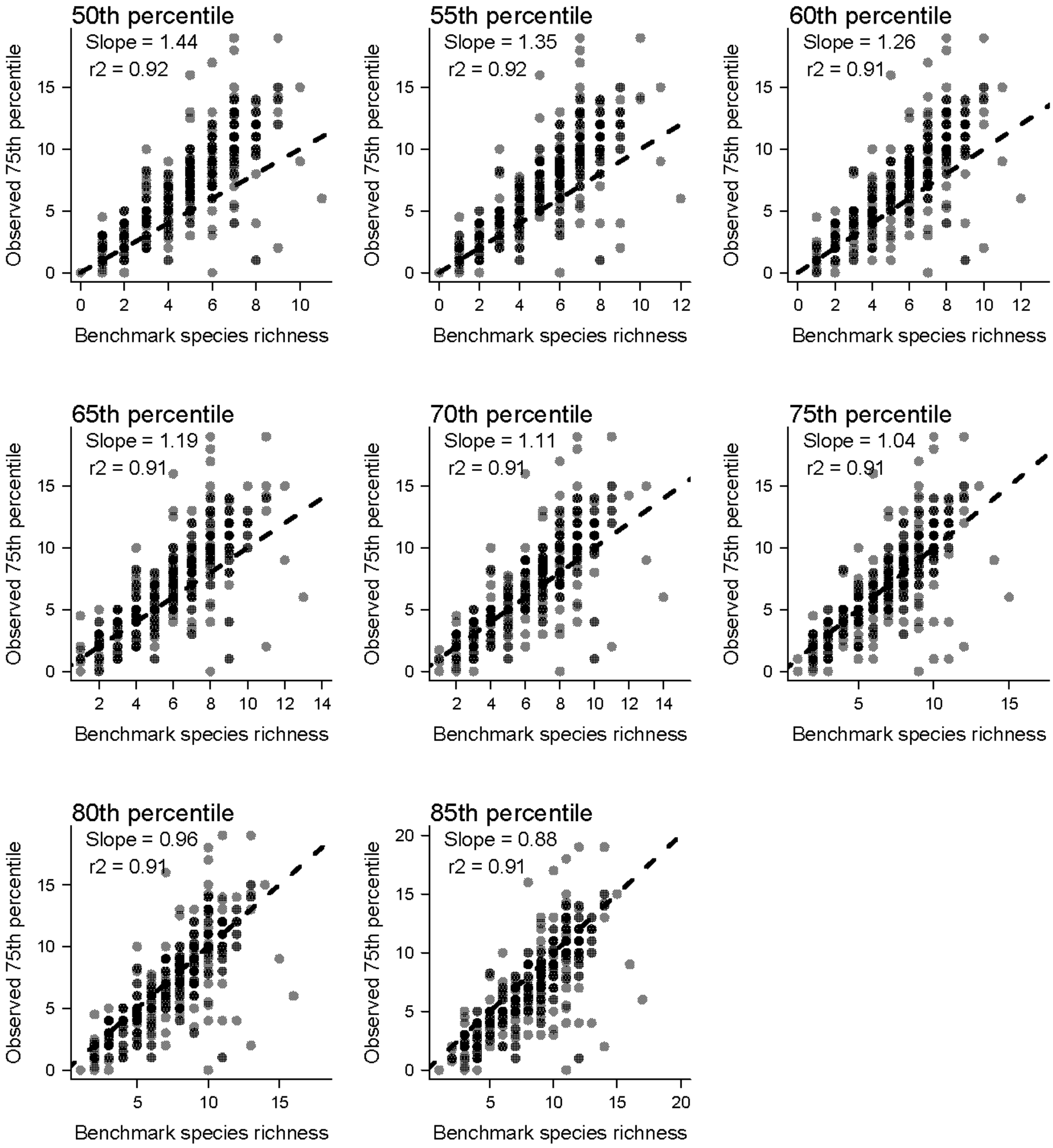

Figure 4 **Estimated versus observed grass richness percentiles for RVCs with > 0 plots**

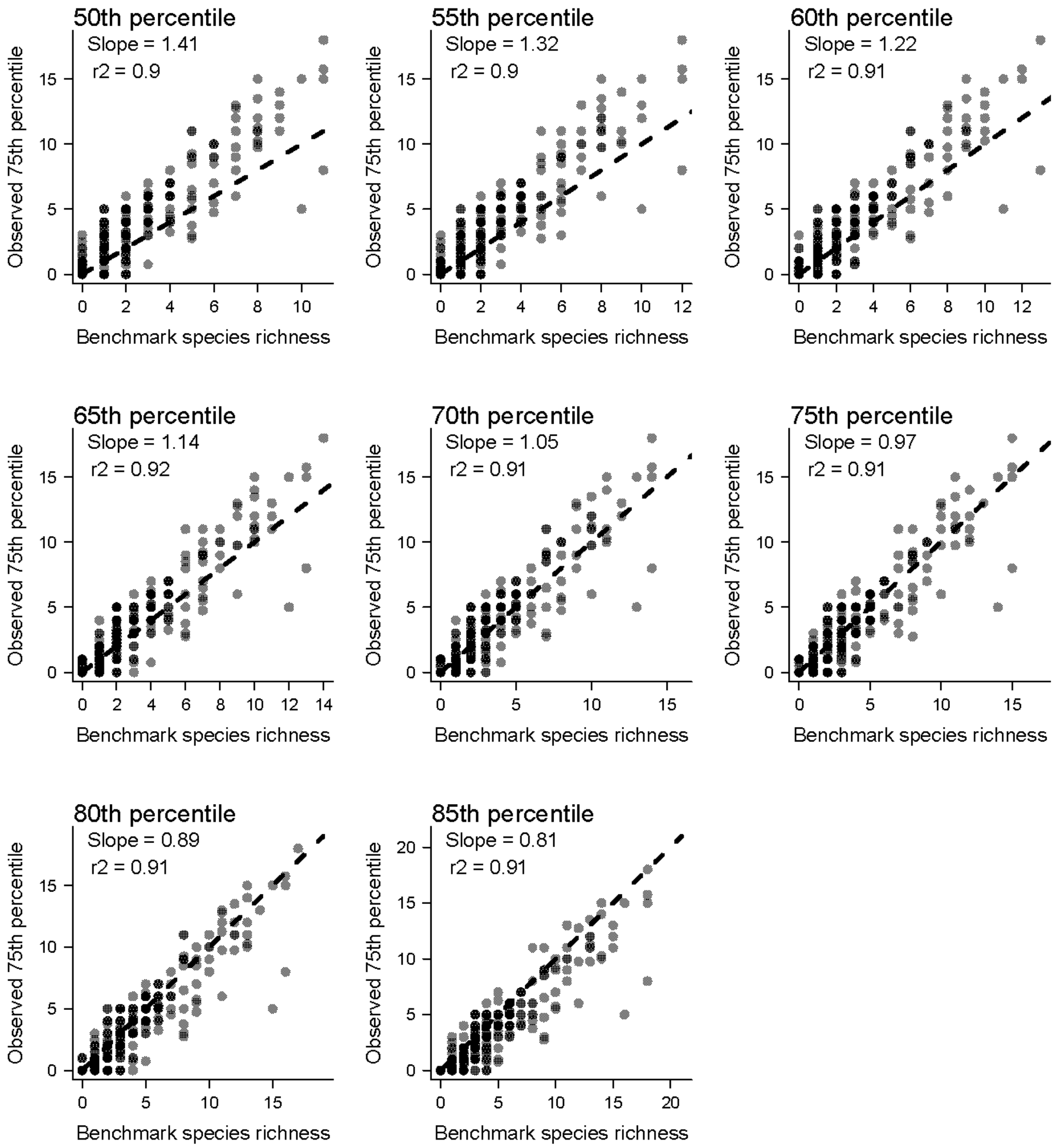

Figure 5 Estimated versus observed other richness percentiles for RVCs with > 0 plots

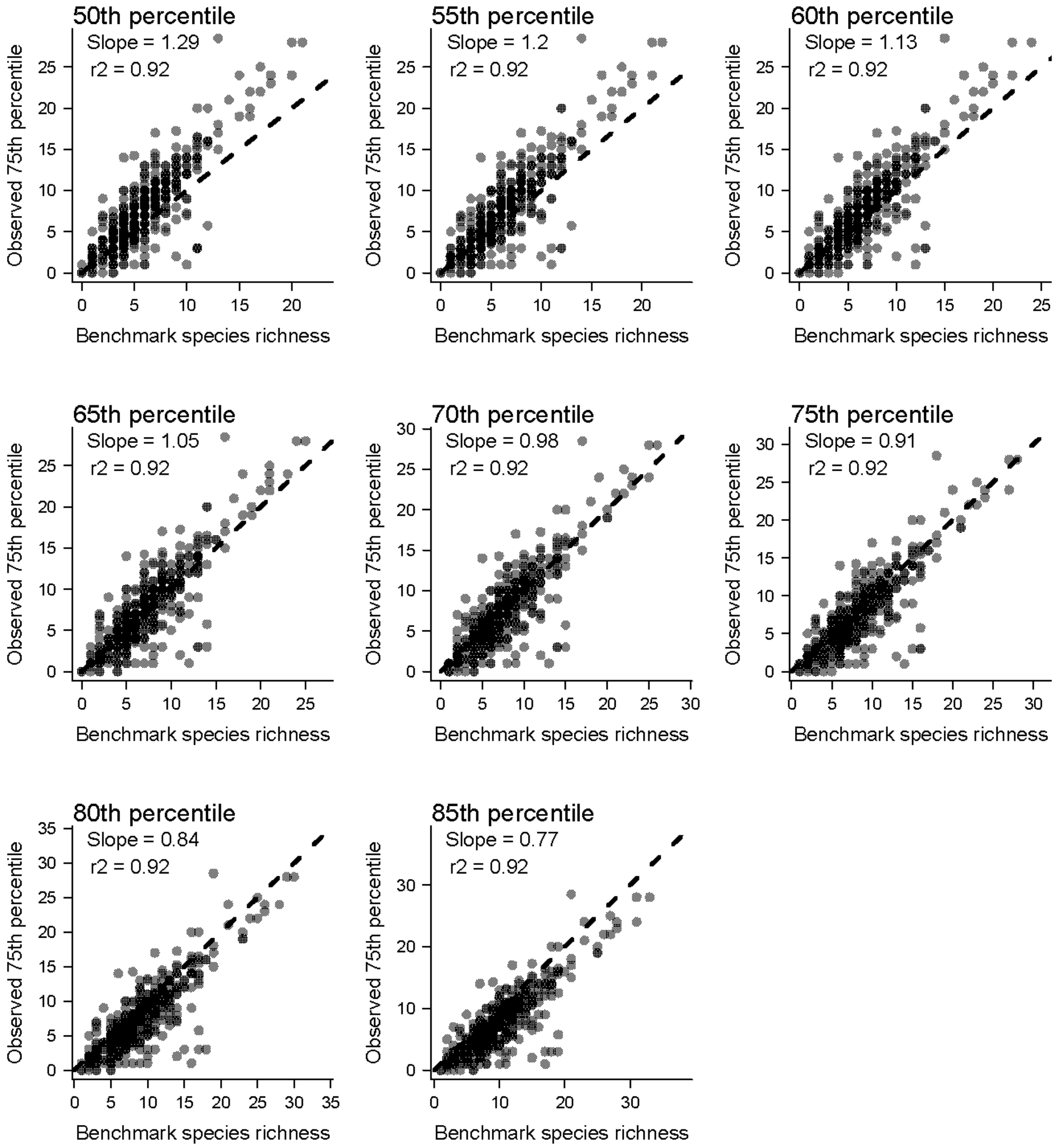

Figure 6 **Estimated versus observed shrub richness percentiles for RVCs with > 0 plots**

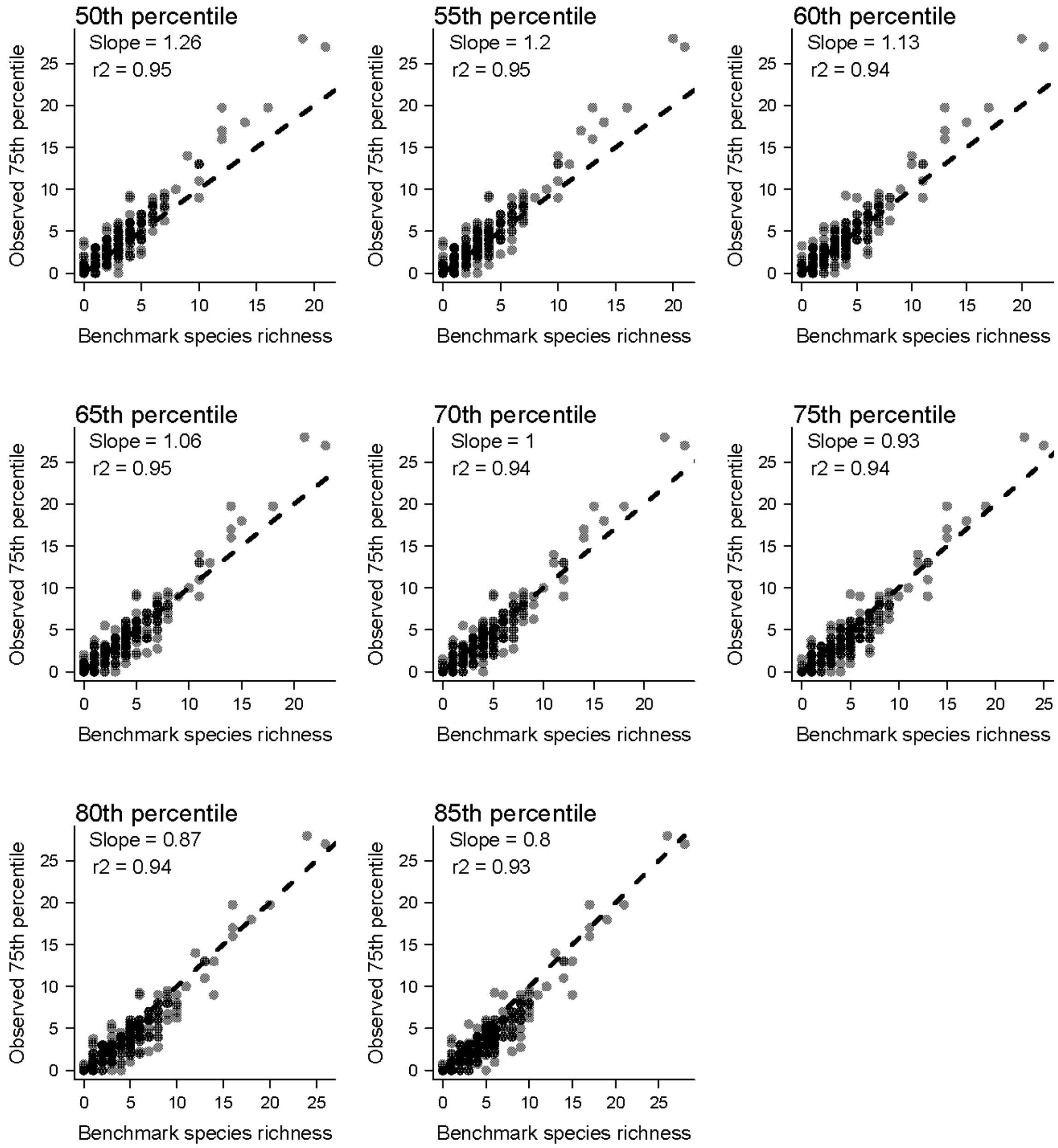

Figure 7 Estimated versus observed tree richness percentiles for RVCs with > 0 plots

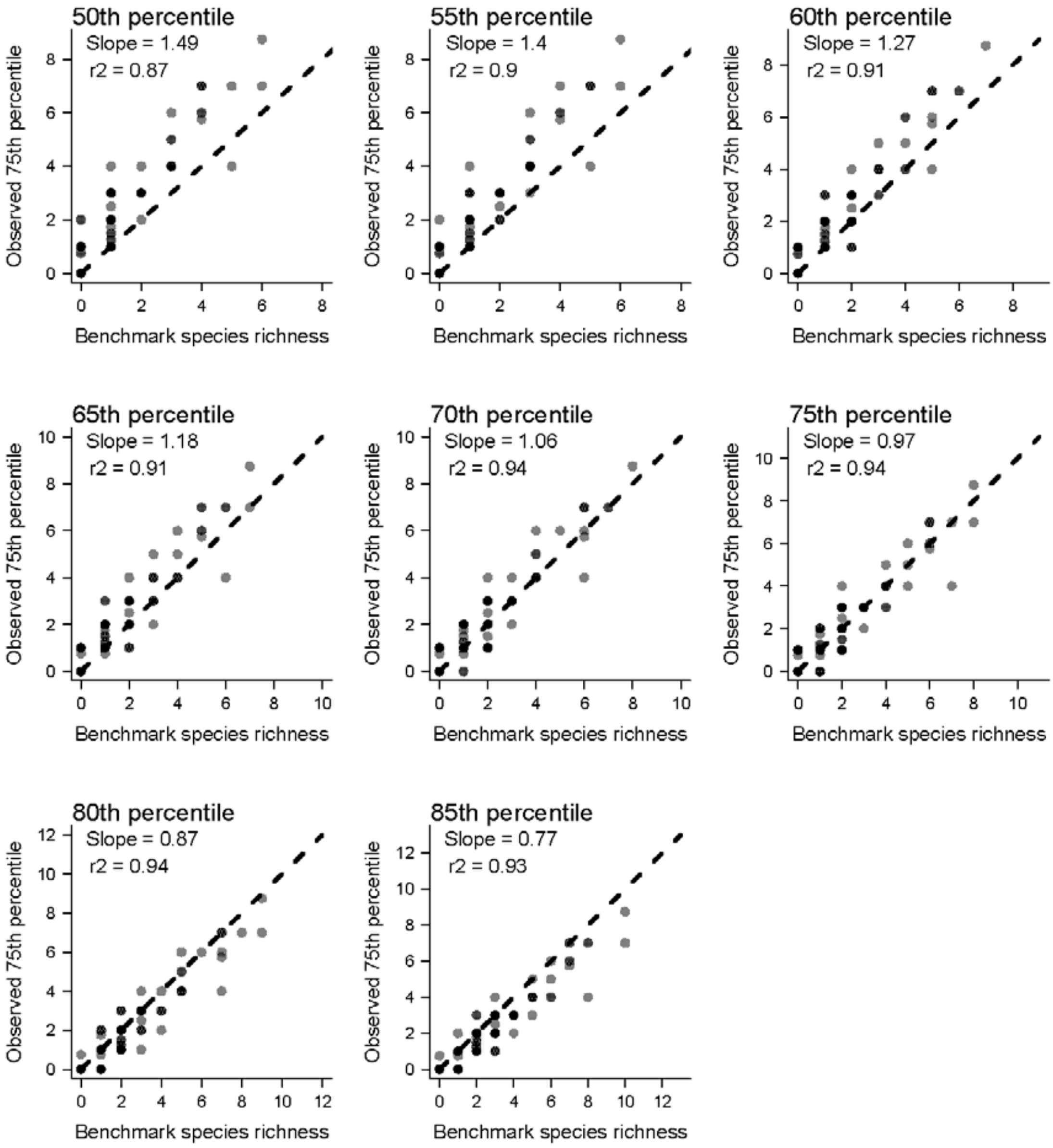

Figure 8 Estimated versus observed fern richness percentiles for RVCs with > 20 plots

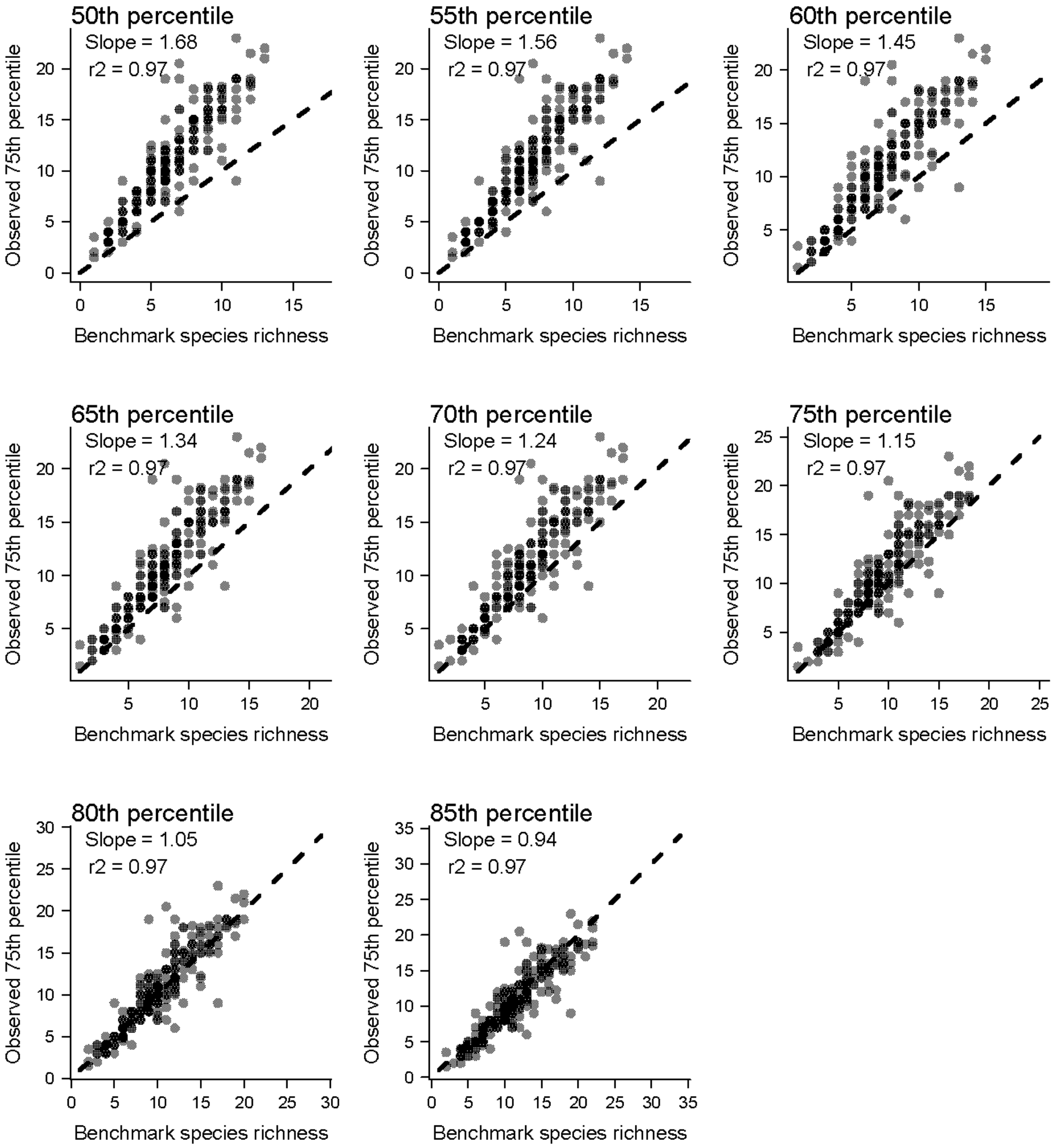

Figure 9 Estimated versus observed forb richness percentiles for RVCs with > 20 plots

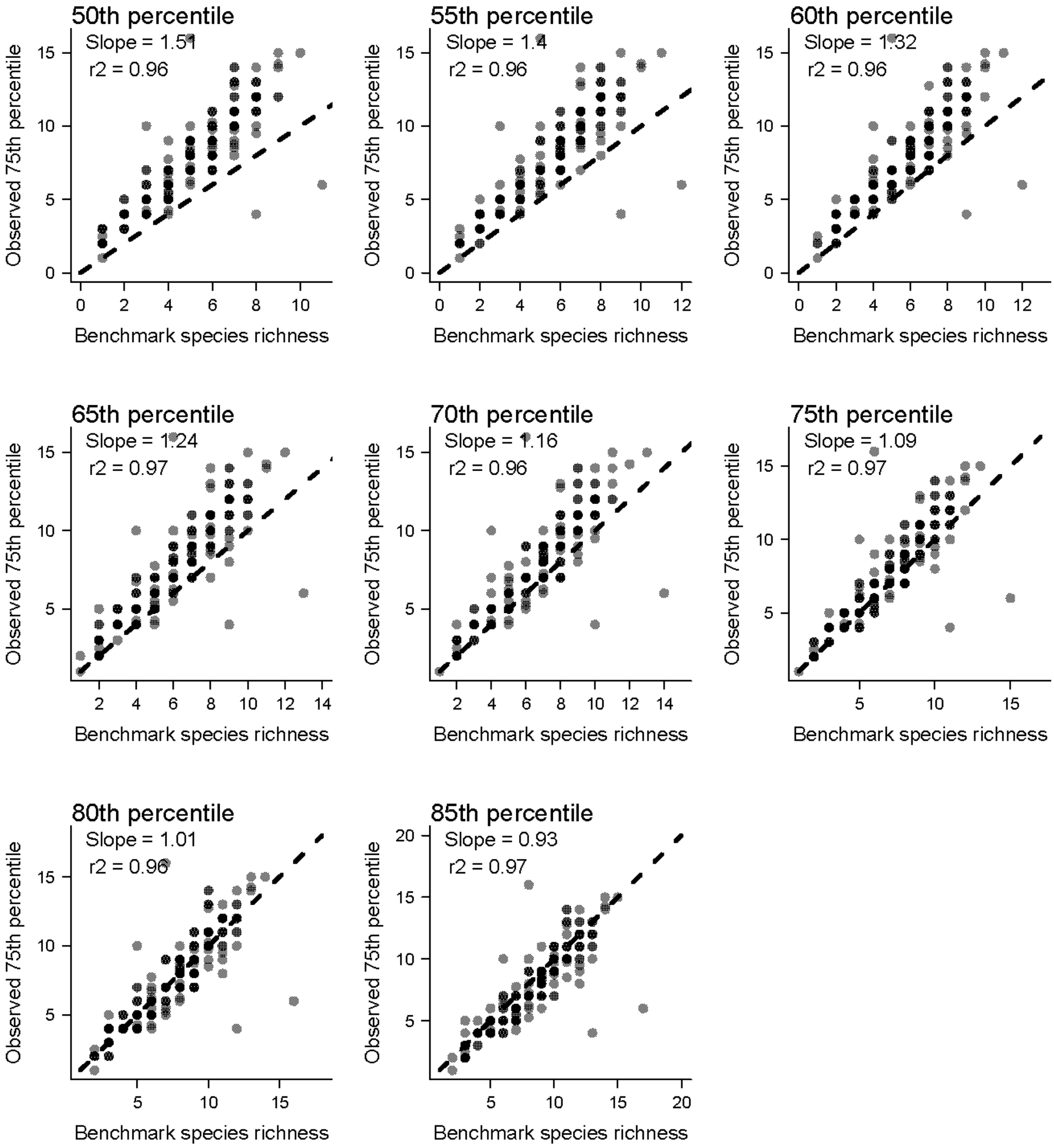

Figure 10 Estimated versus observed grass richness percentiles for RVCs with > 20 plots

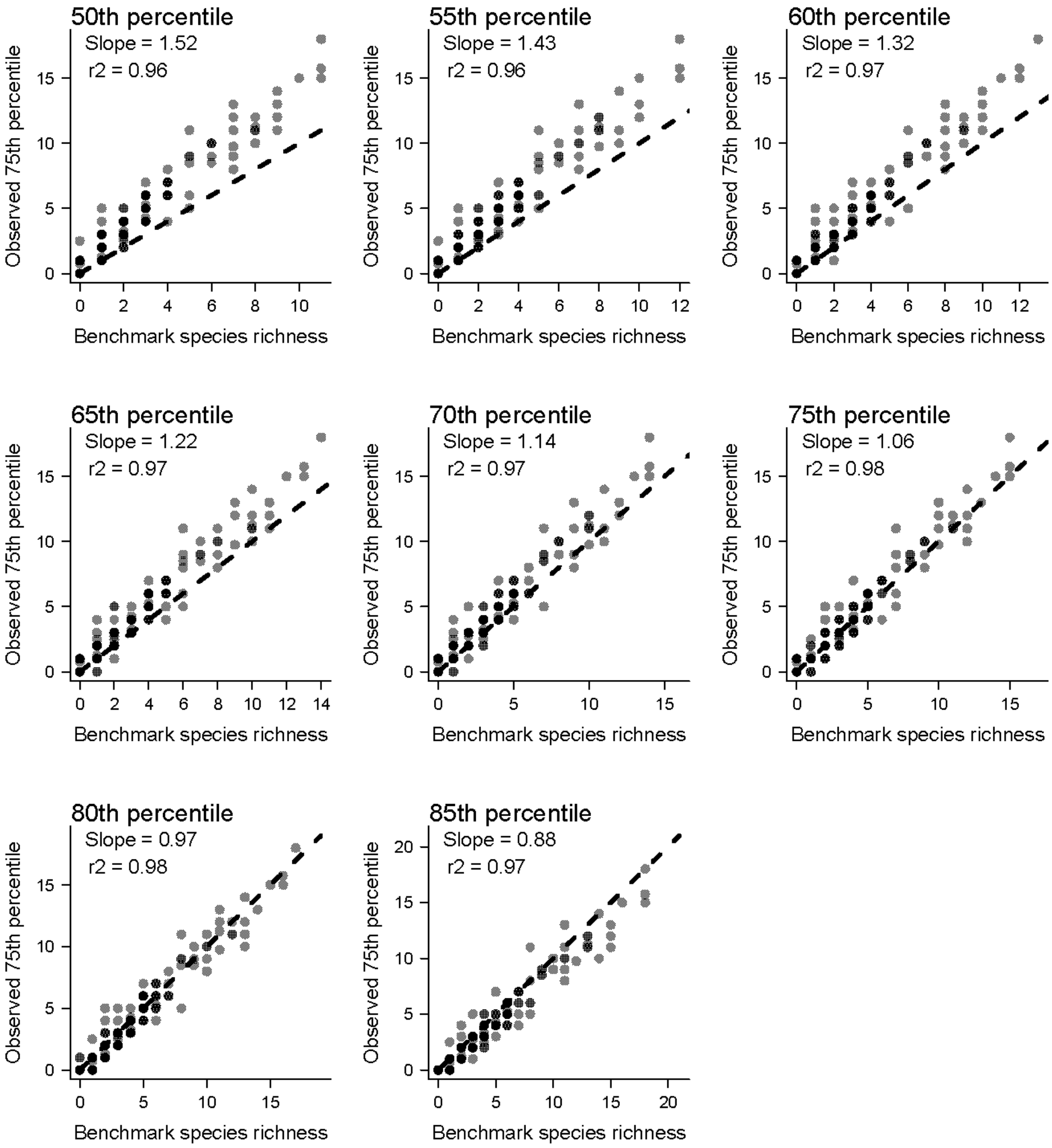

Figure 11 Estimated versus observed other richness percentiles for RVCs with > 20 plots

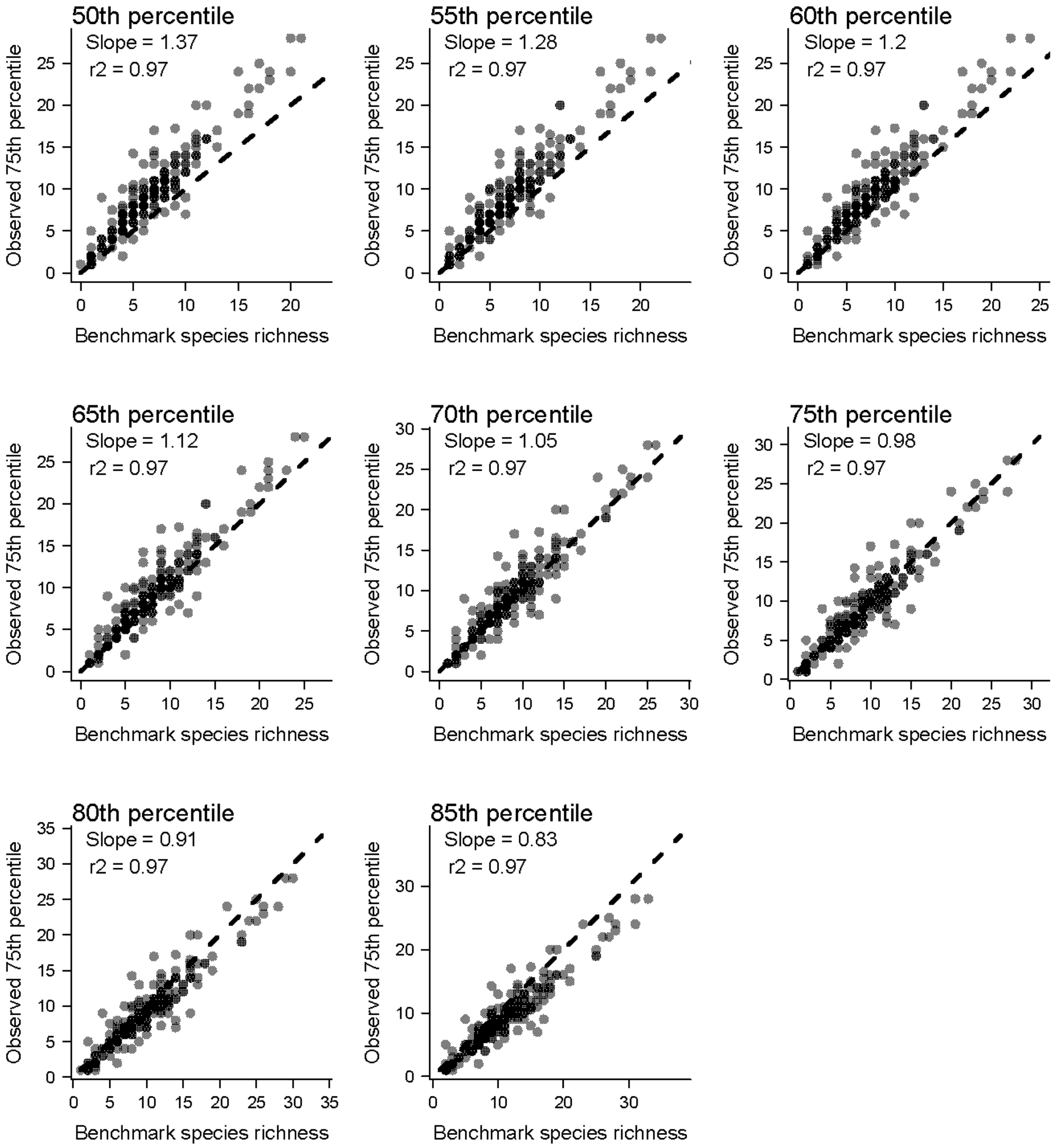

Figure 12 Estimated versus observed shrub richness percentiles for RVCs with > 20 plots

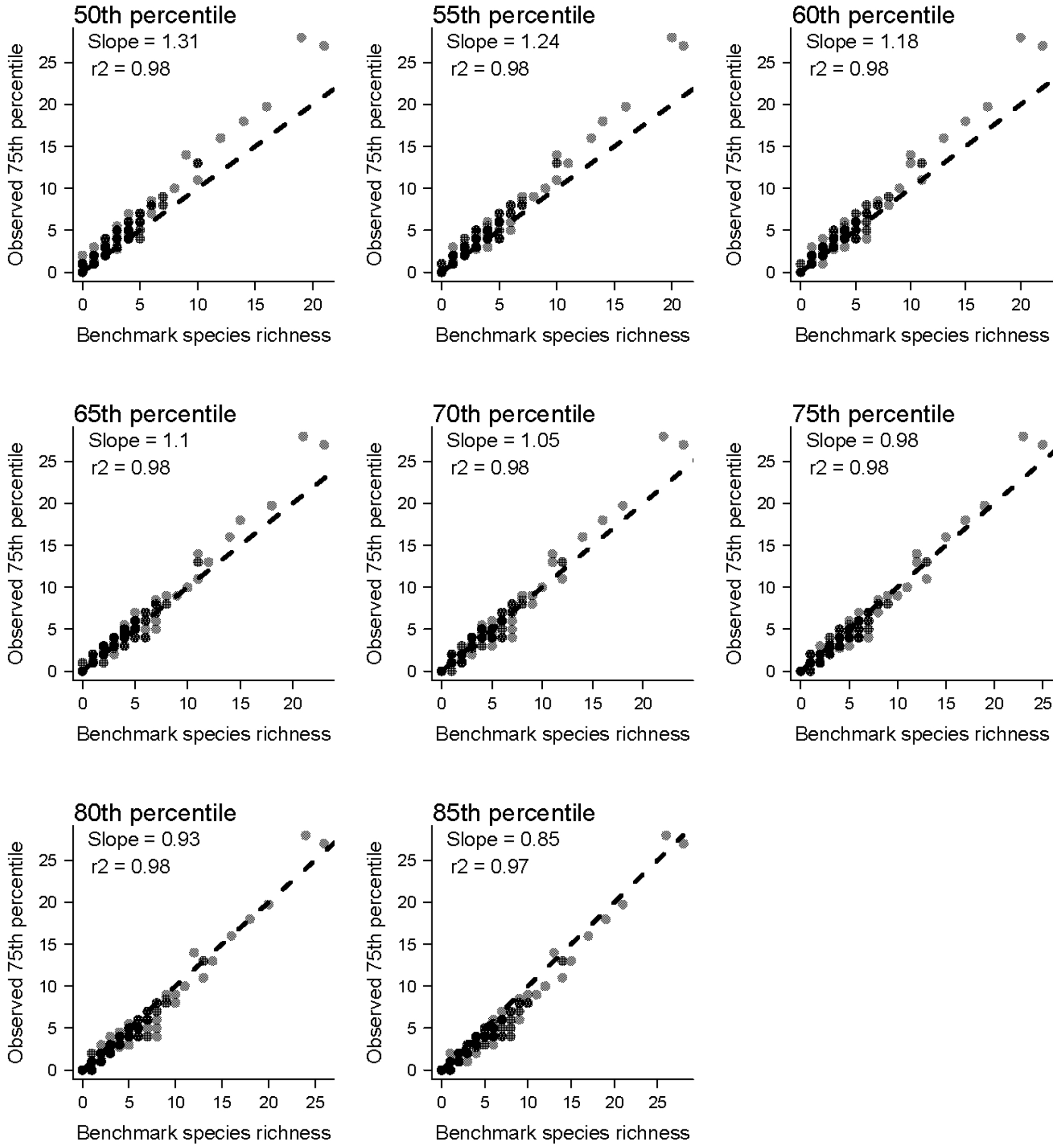

Figure 13 Estimated versus observed tree richness percentiles for RVCs with > 20 plots

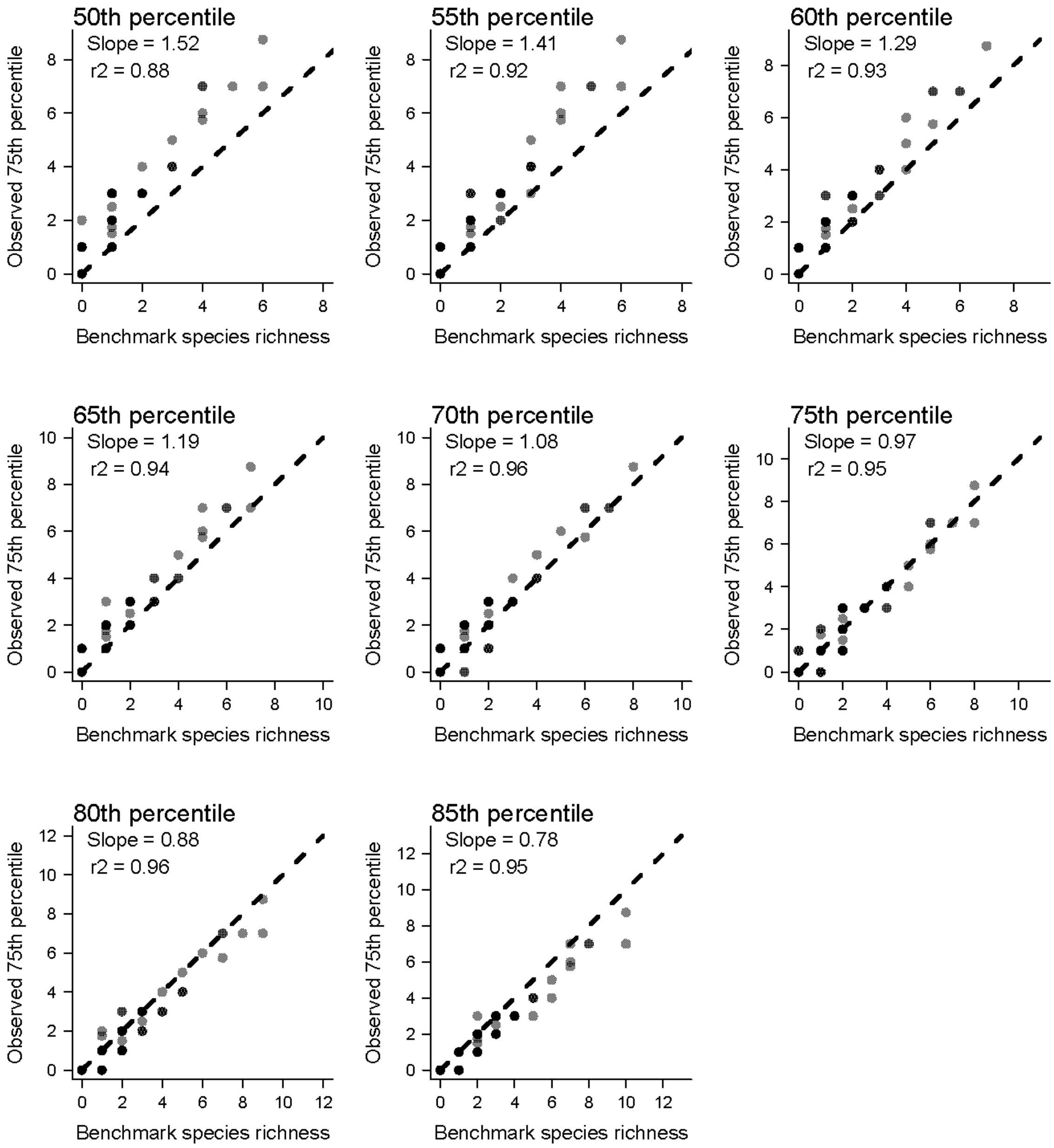

Figure 14 Estimated versus observed fern richness percentiles for RVCs with > 50 plots

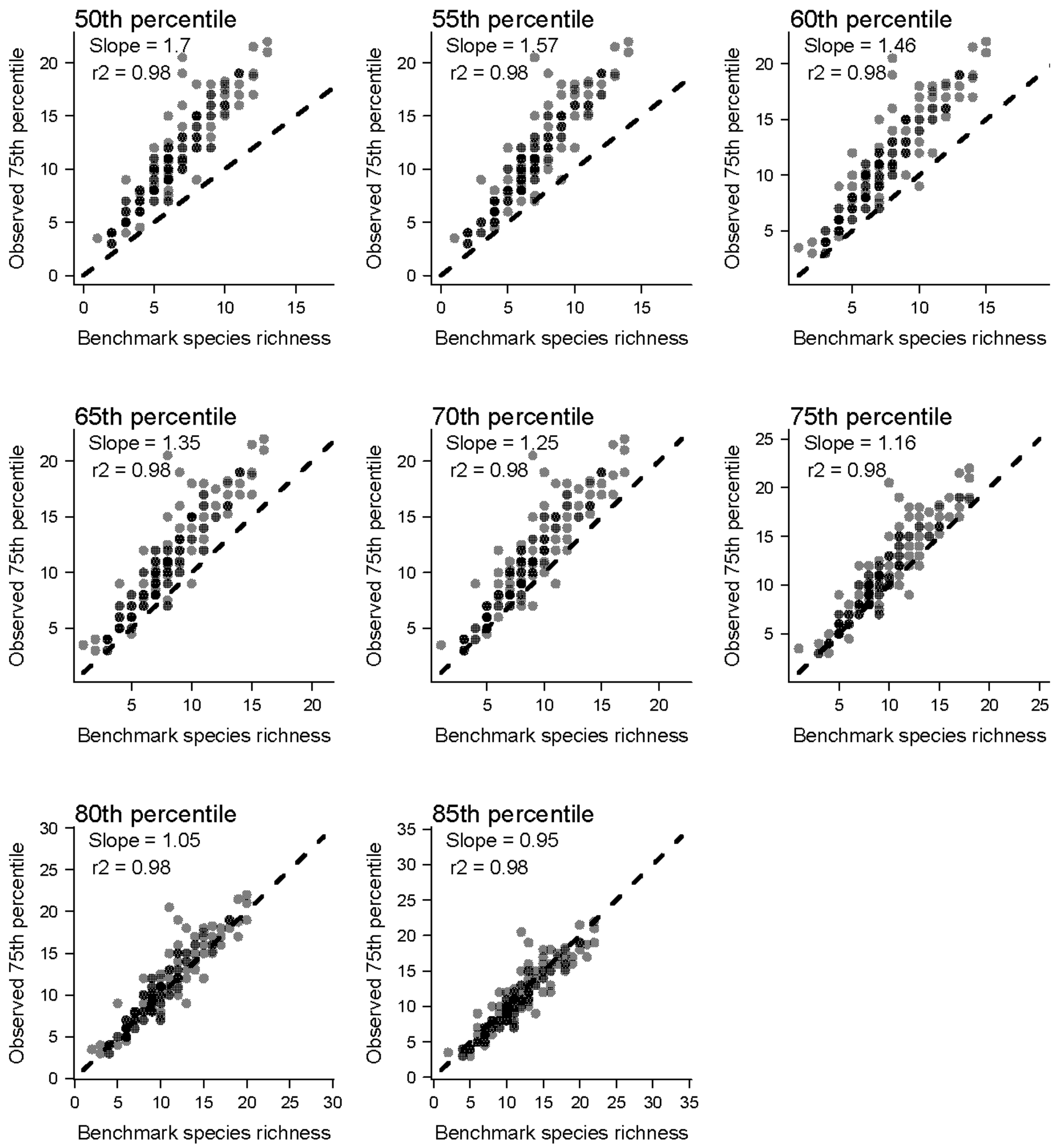

Figure 15 **Estimated versus observed forb richness percentiles for RVCs with > 50 plots**

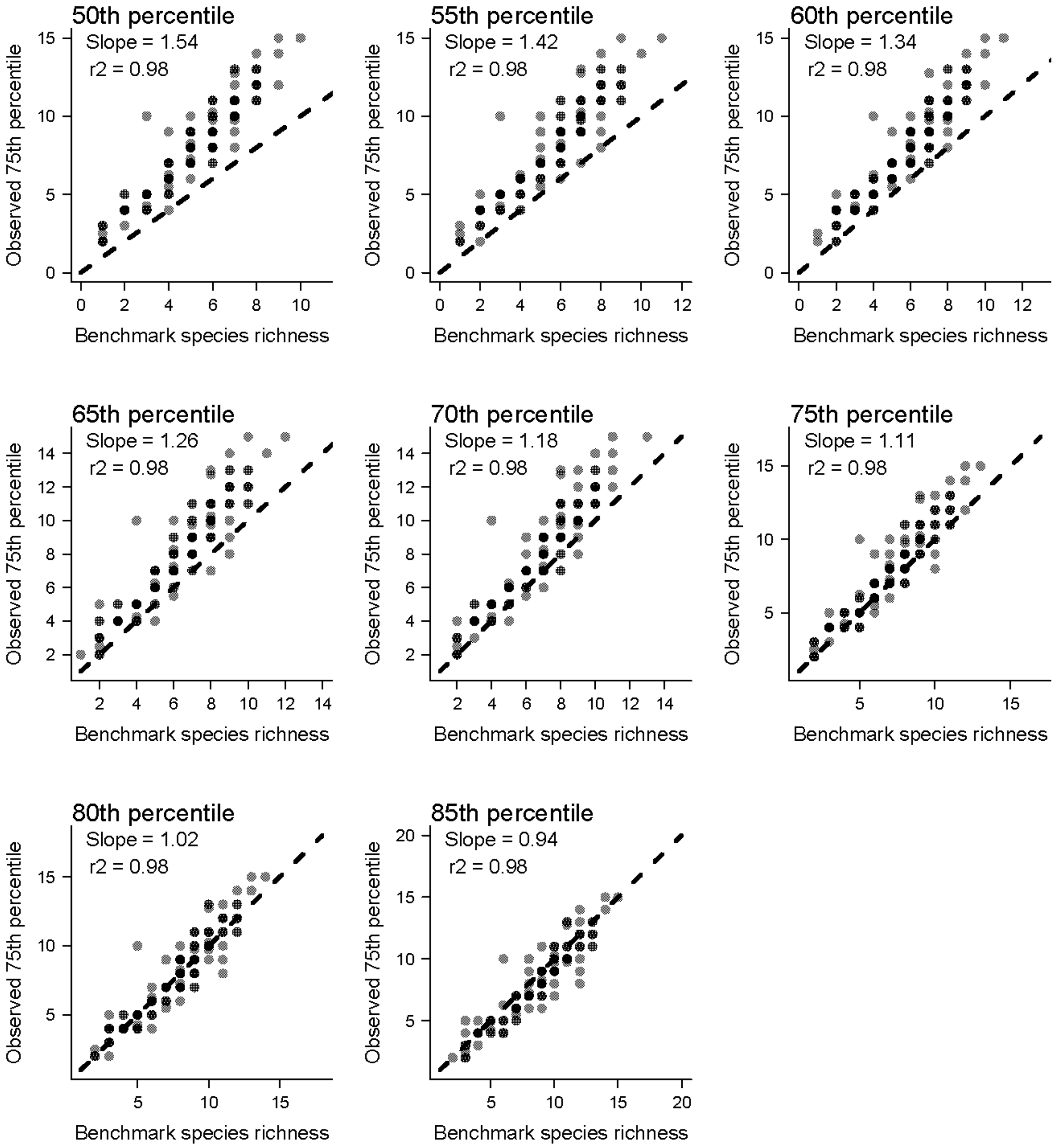

Figure 16 **Estimated versus observed grass richness percentiles for RVCs with > 50 plots**

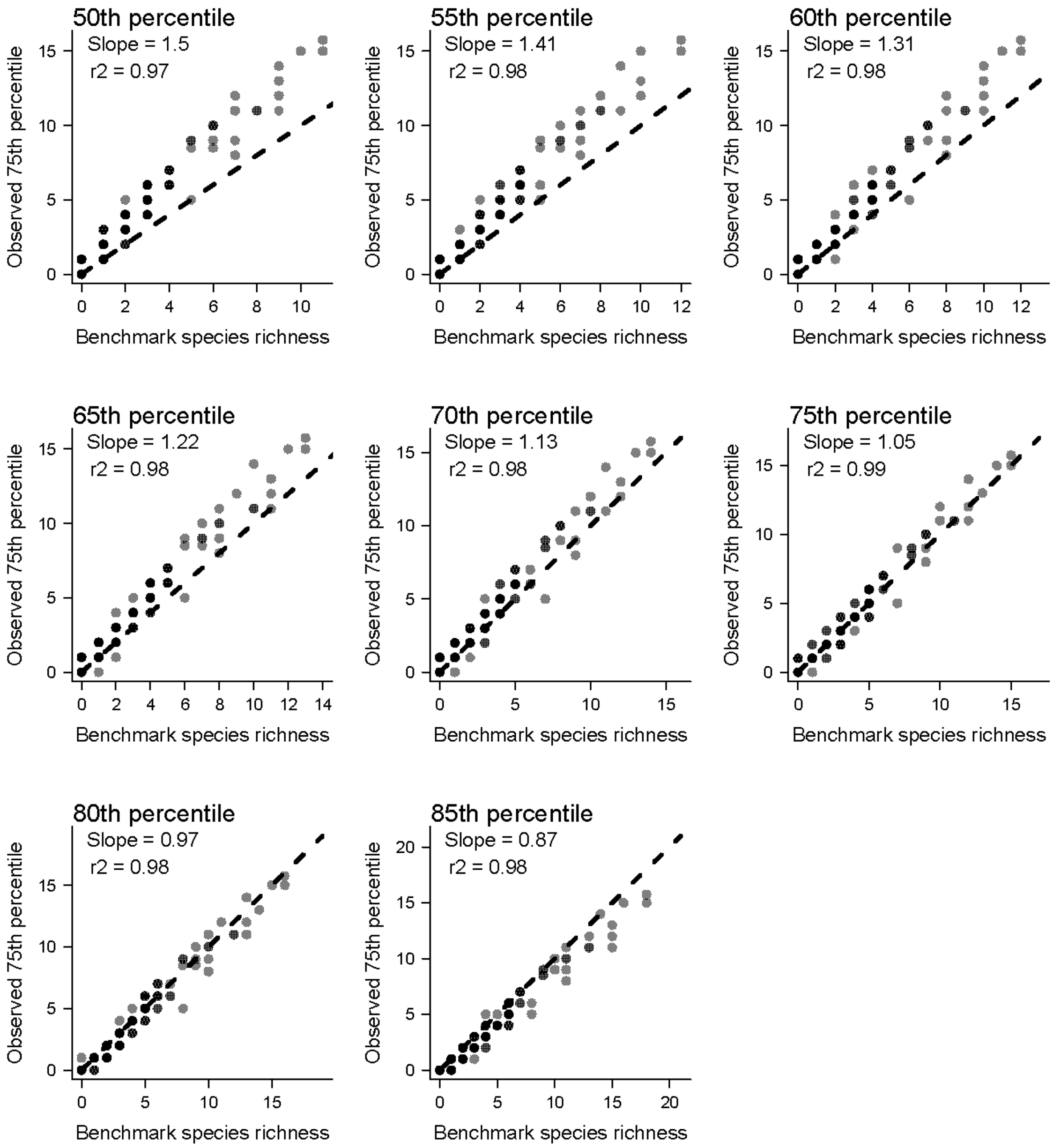

Figure 17 Estimated versus observed other richness percentiles for RVCs with > 50 plots

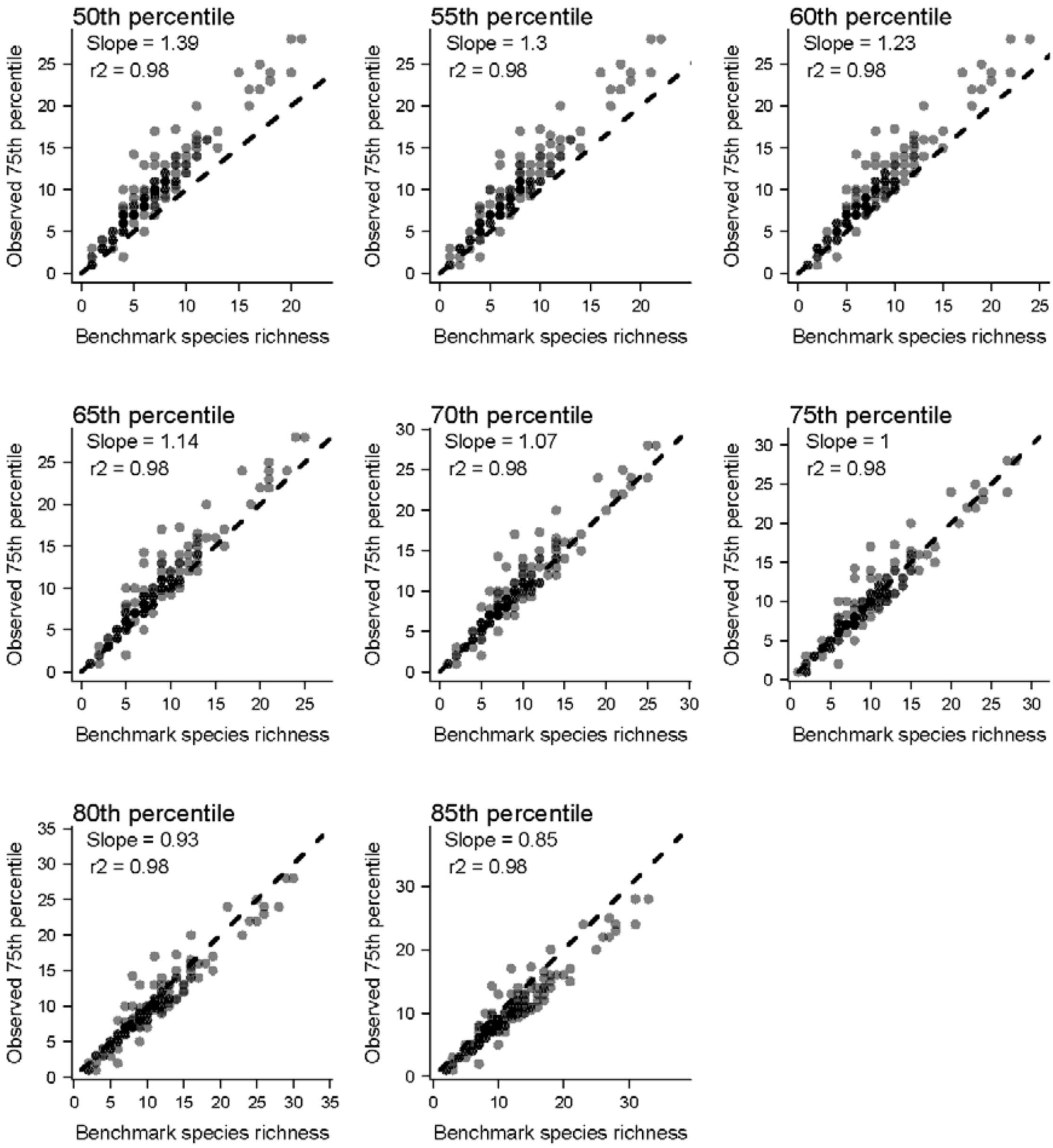

Figure 18 Estimated versus observed shrub richness percentiles for RVCs with > 50 plots

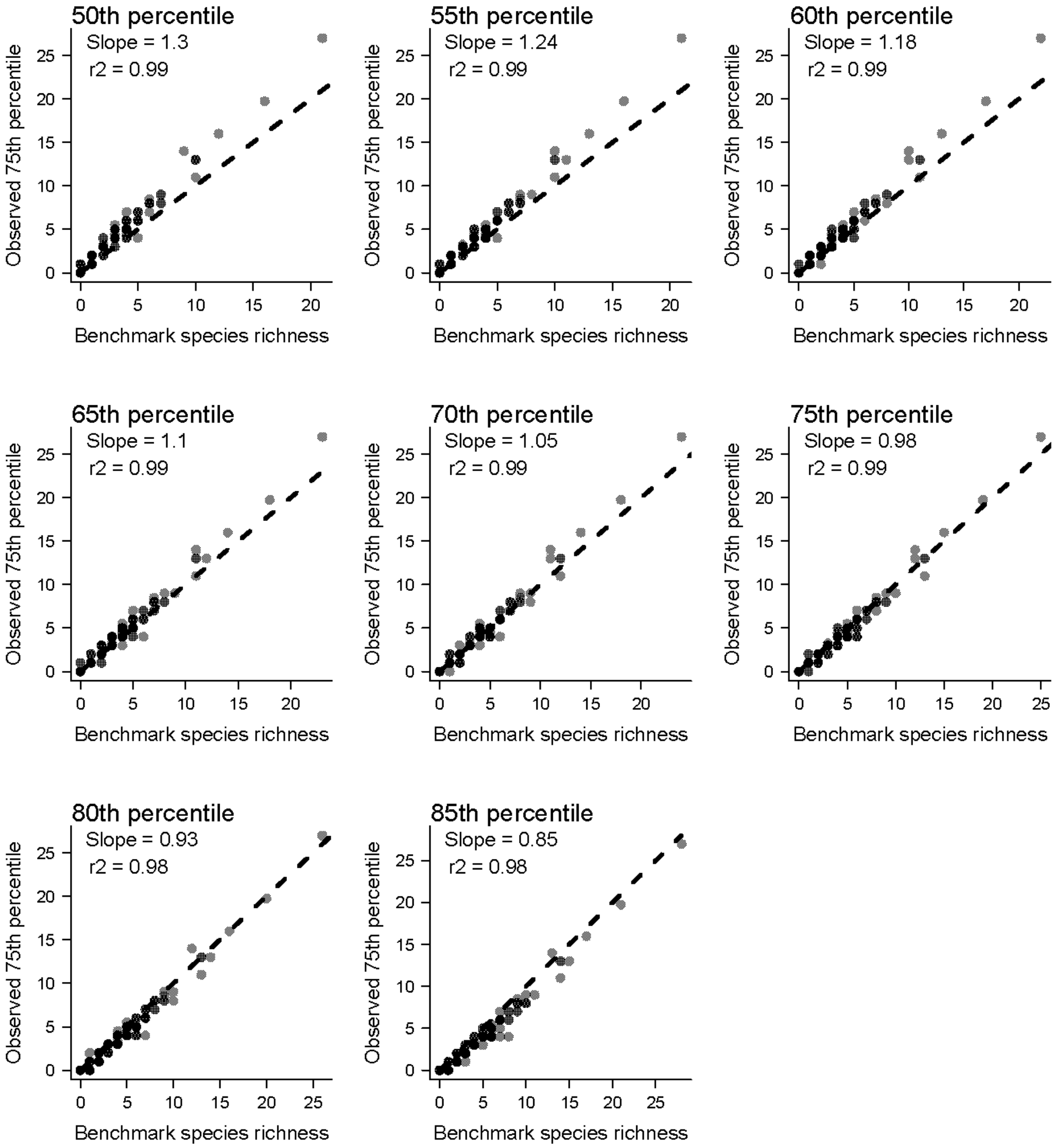

Figure 19 Estimated versus observed tree richness percentiles for RVCs with > 50 plots

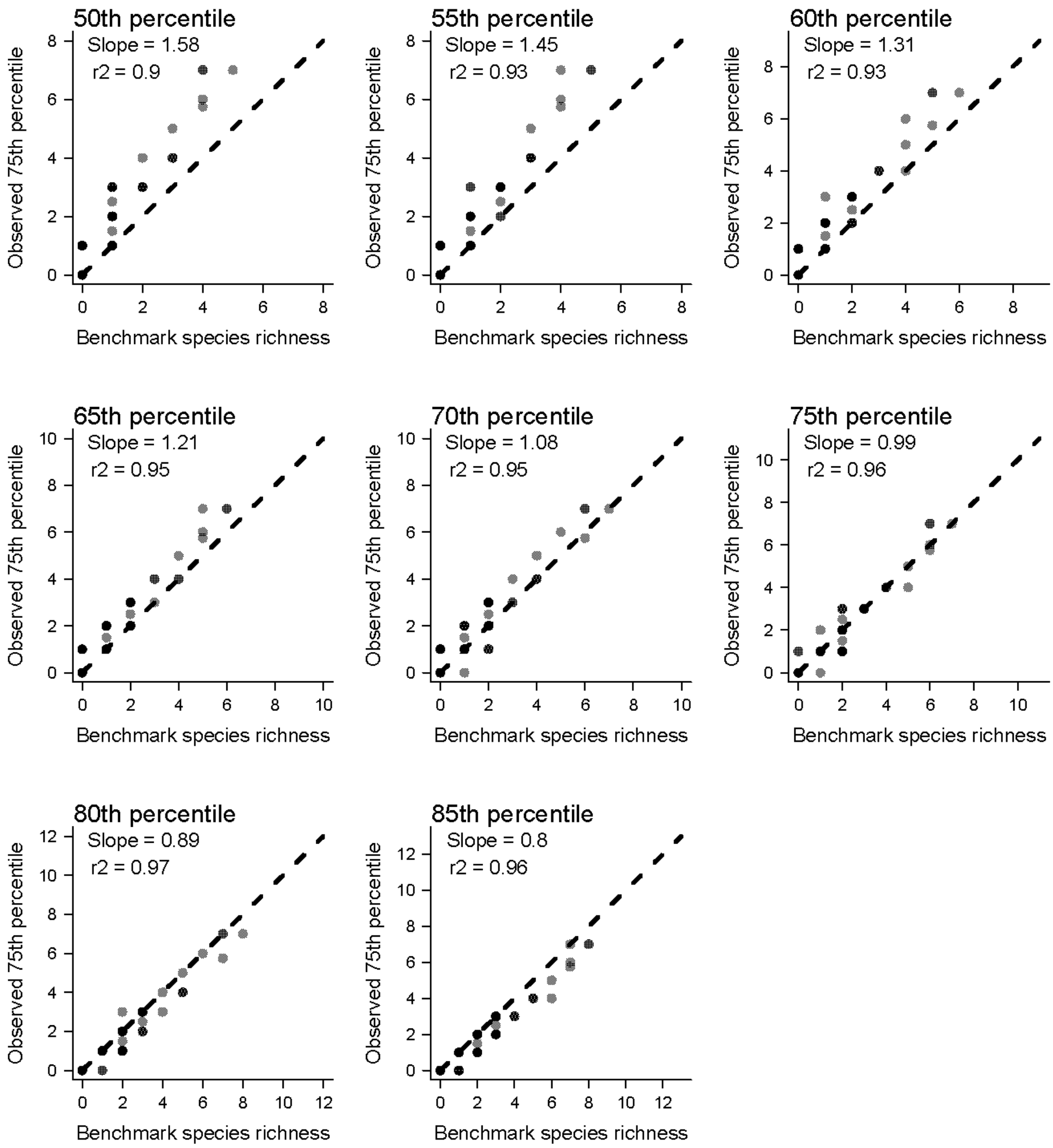

Figure 20 **Estimated versus observed fern richness percentiles for RVCs with > 100 plots**

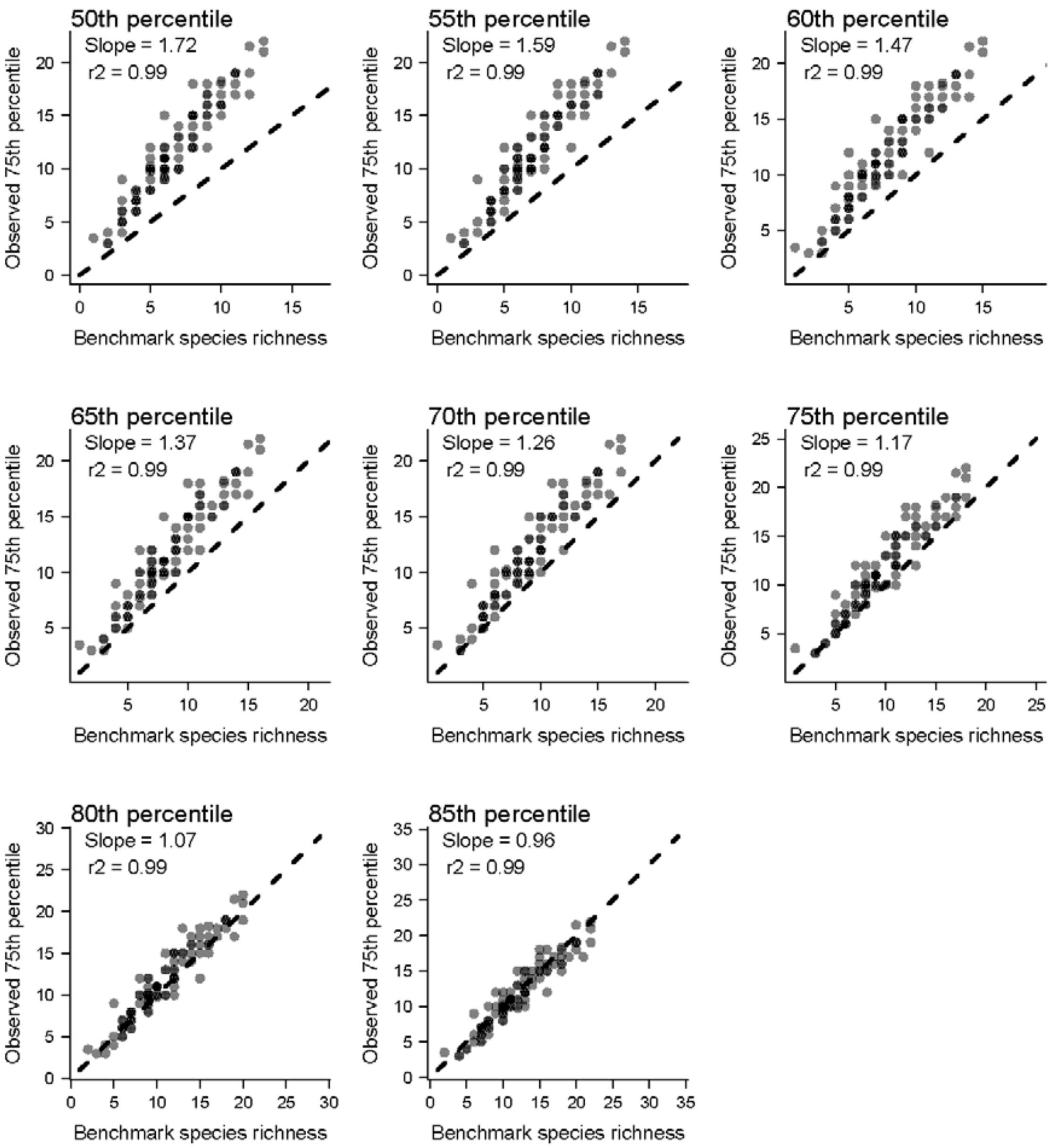

Figure 21 Estimated versus observed forb richness percentiles for RVCs with > 100 plots

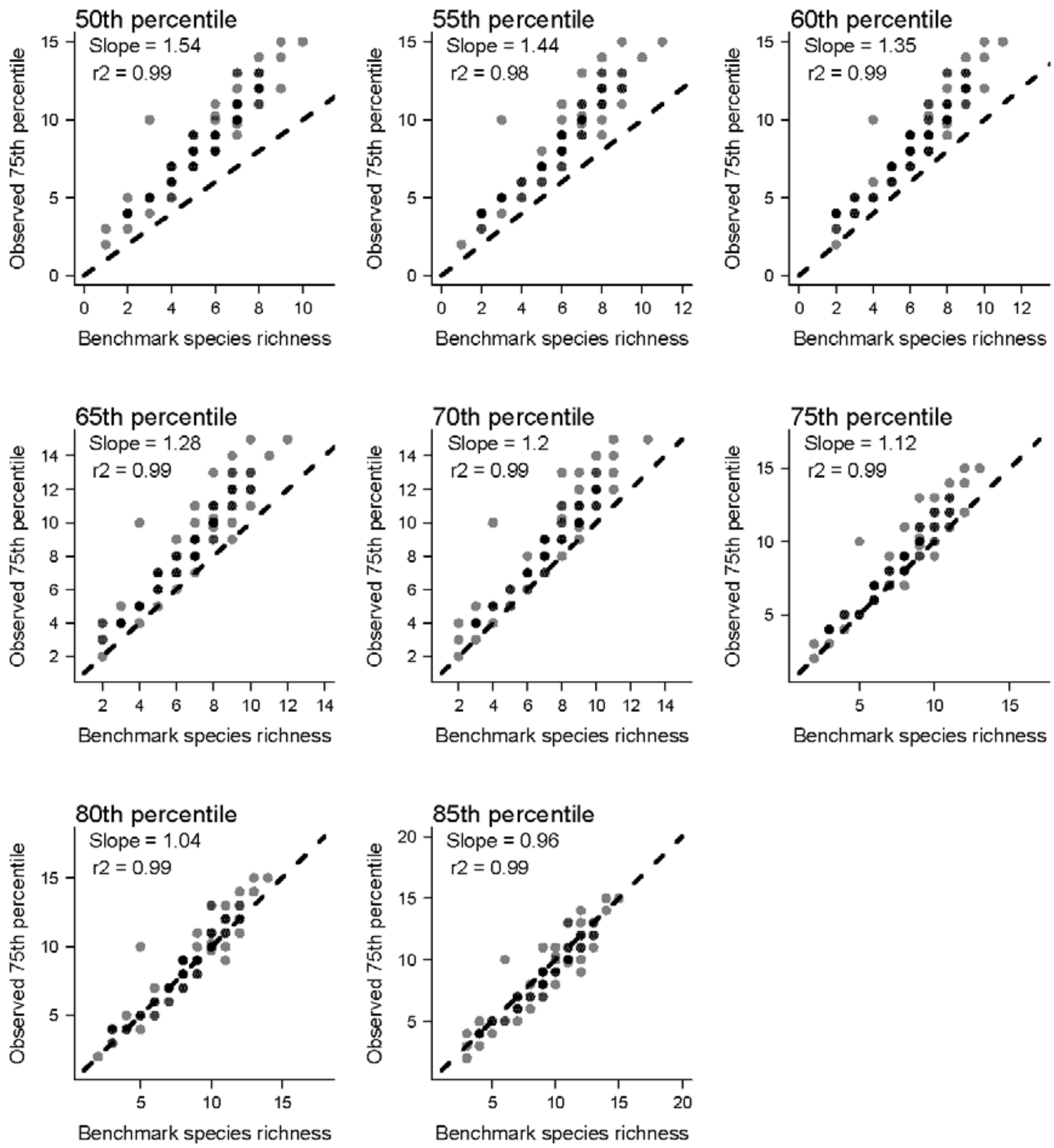

Figure 22 **Estimated versus observed grass richness percentiles for RVCs with > 100 plots**

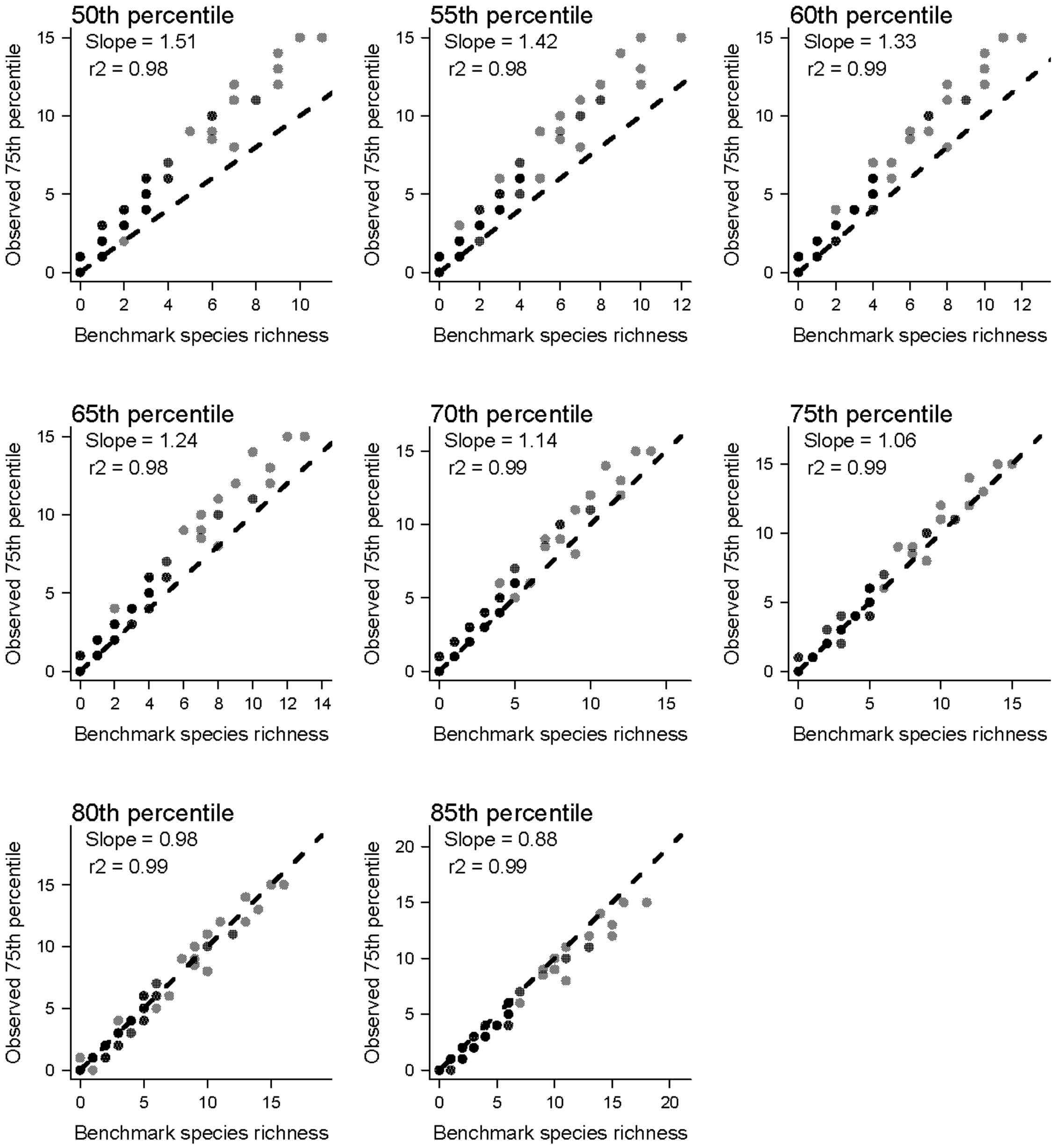

Figure 23 Estimated versus observed other richness percentiles for RVCs with > 100 plots

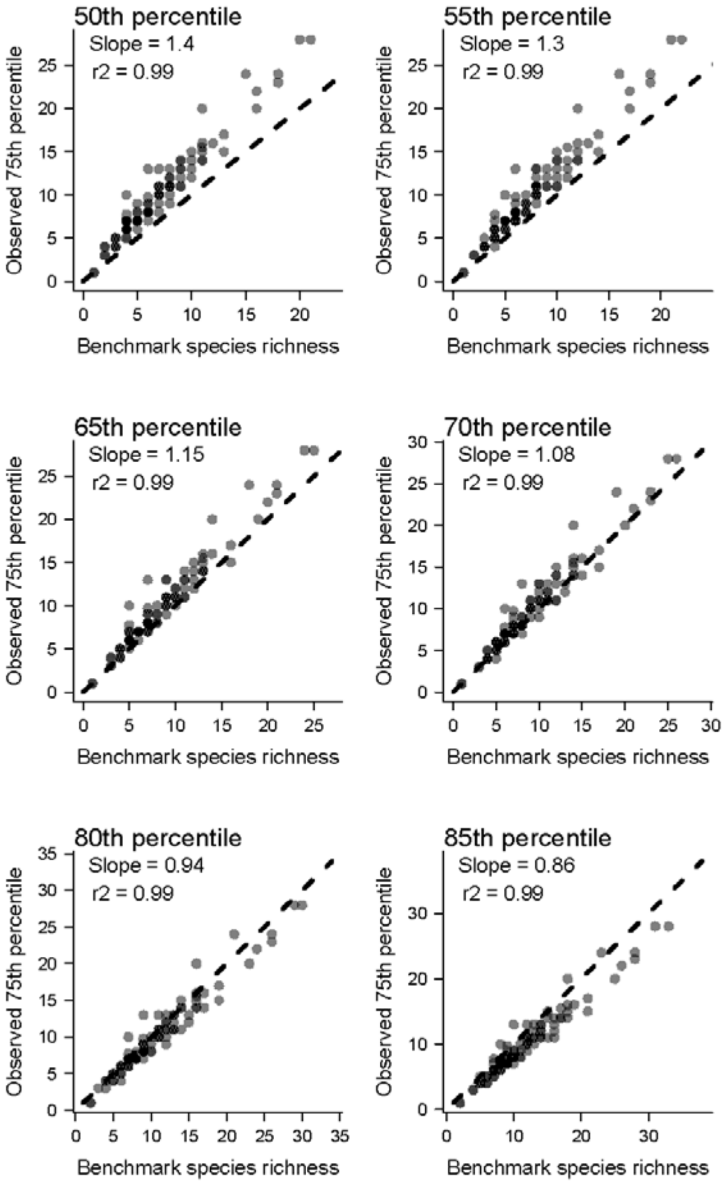

Figure 24 **Estimated versus observed shrub richness percentiles for RVCs with > 100 plots**

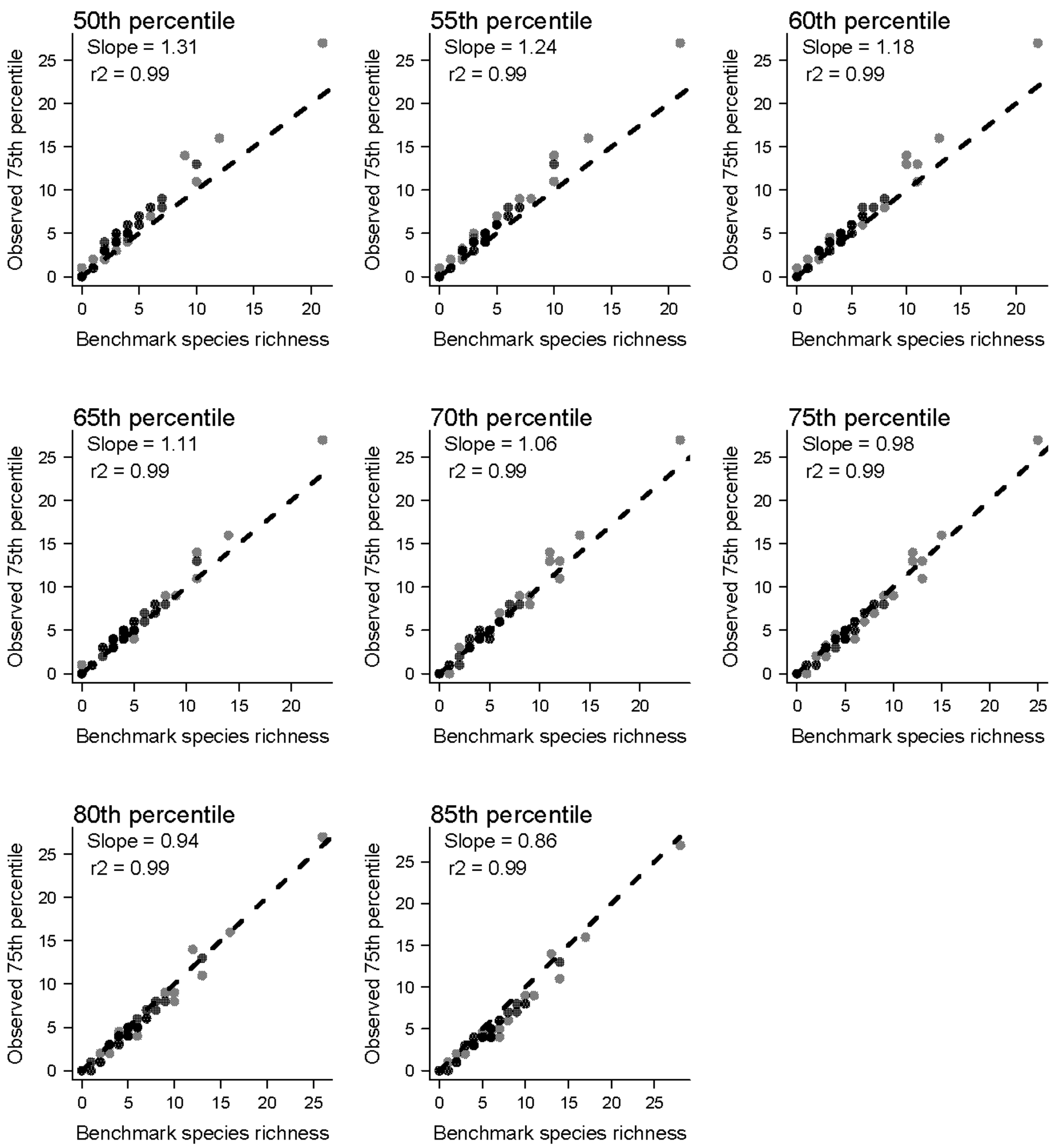

Figure 25 Estimated versus observed tree richness percentiles for RVCs with > 100 plots

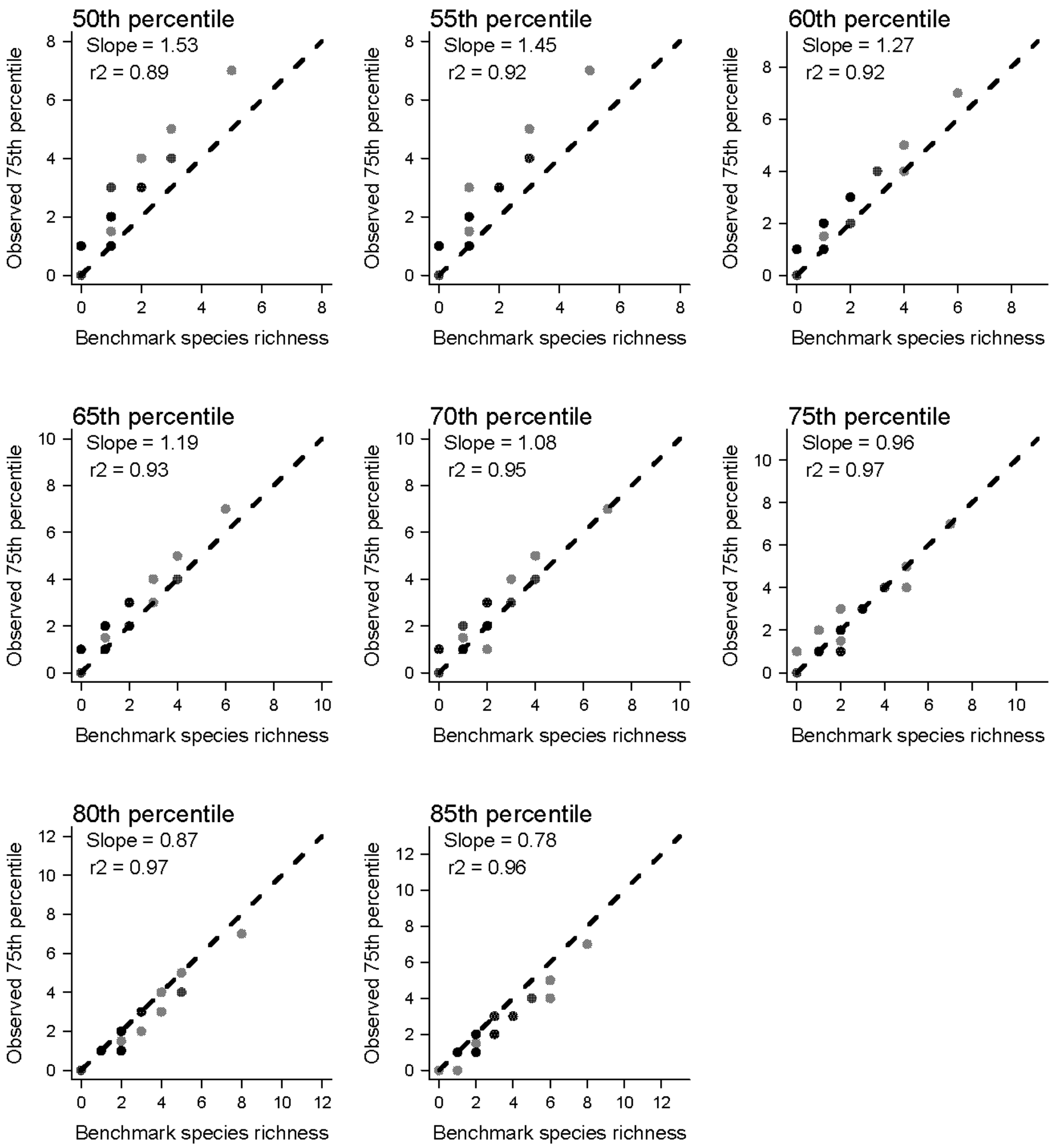

Figure 26 Estimated versus observed fern richness percentiles for RVCs with > 200 plots

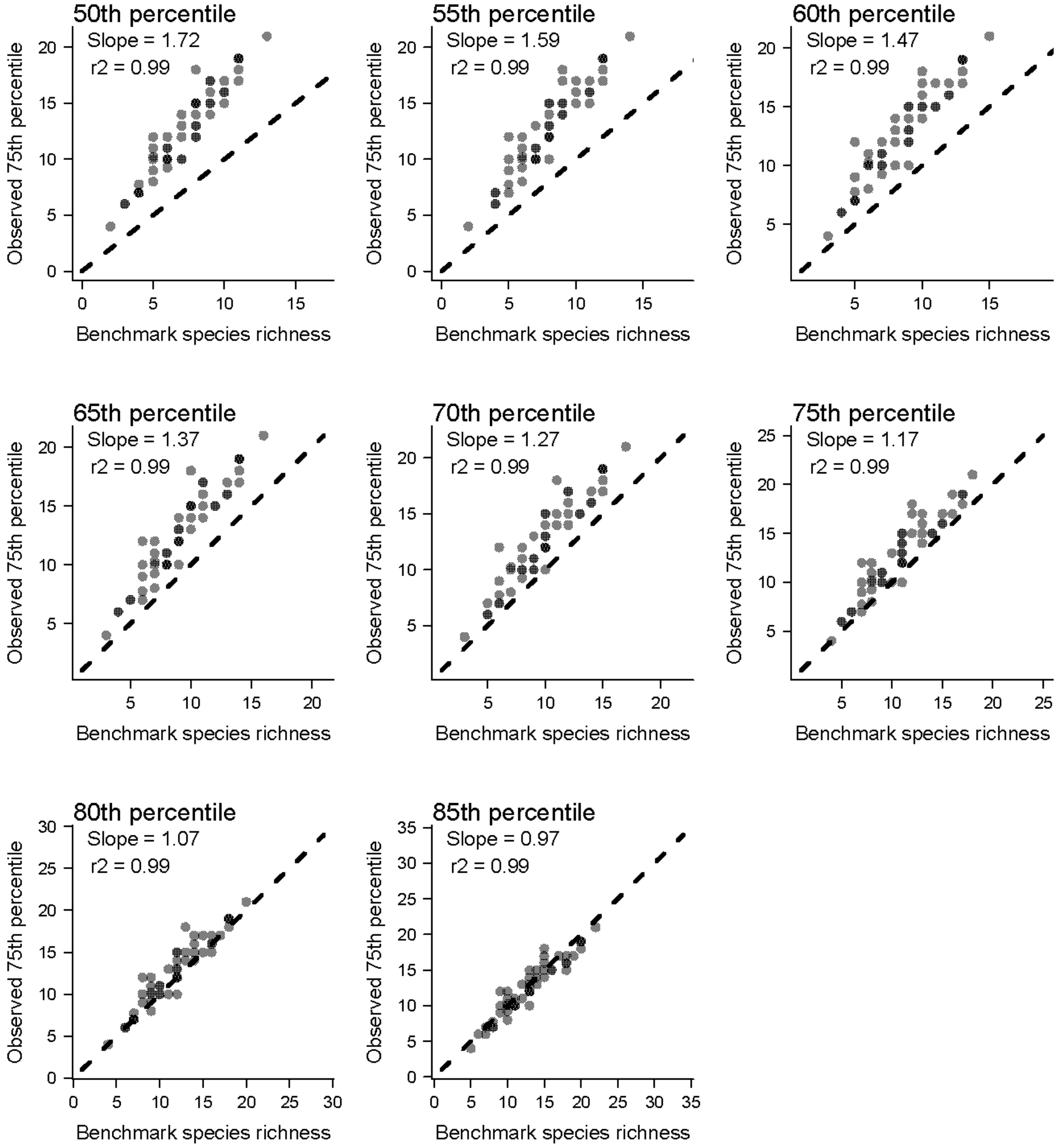

Figure 27 Estimated versus observed forb richness percentiles for RVCs with > 200 plots

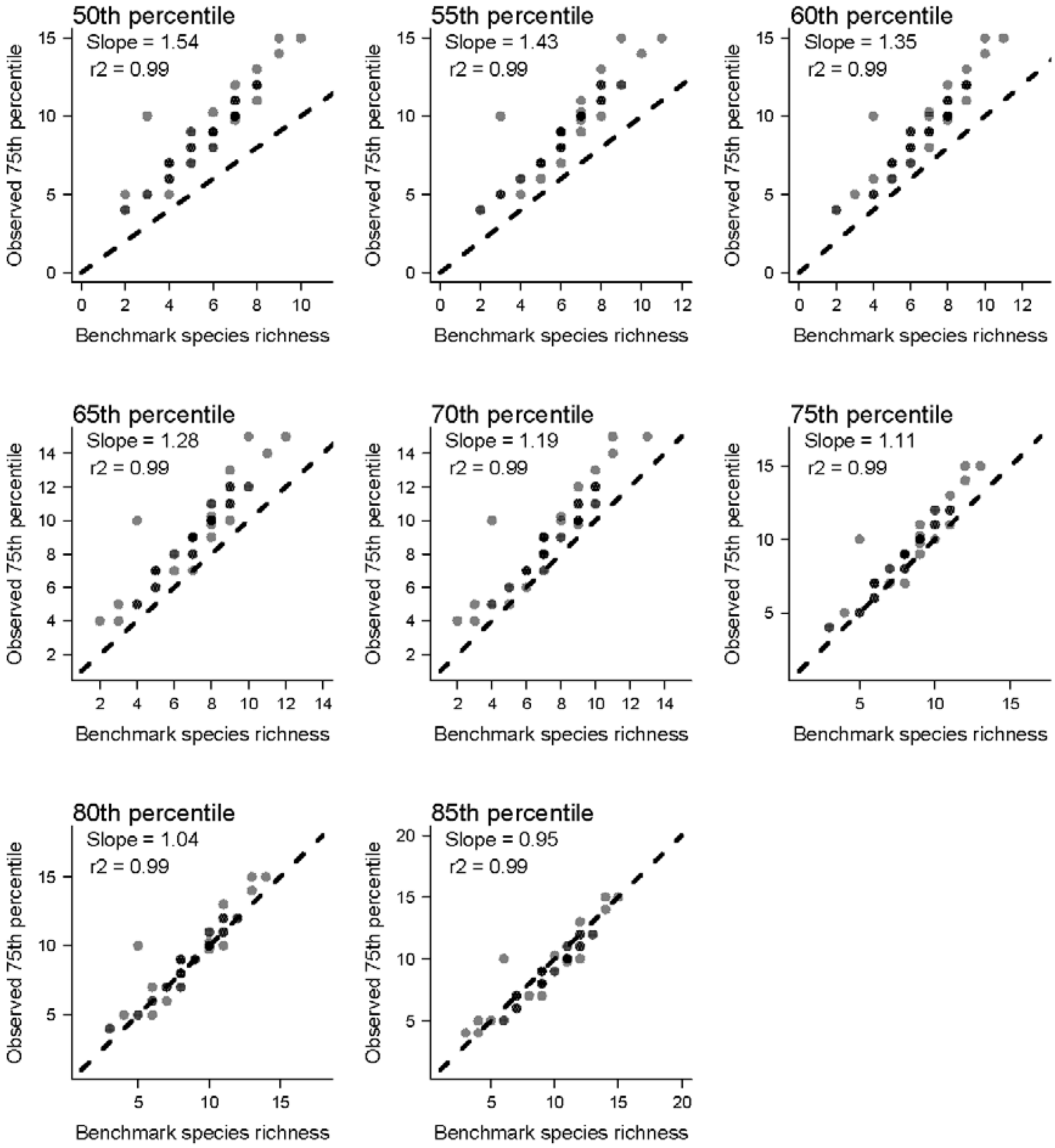

Figure 28 **Estimated versus observed grass richness percentiles for RVCs with > 200 plots**

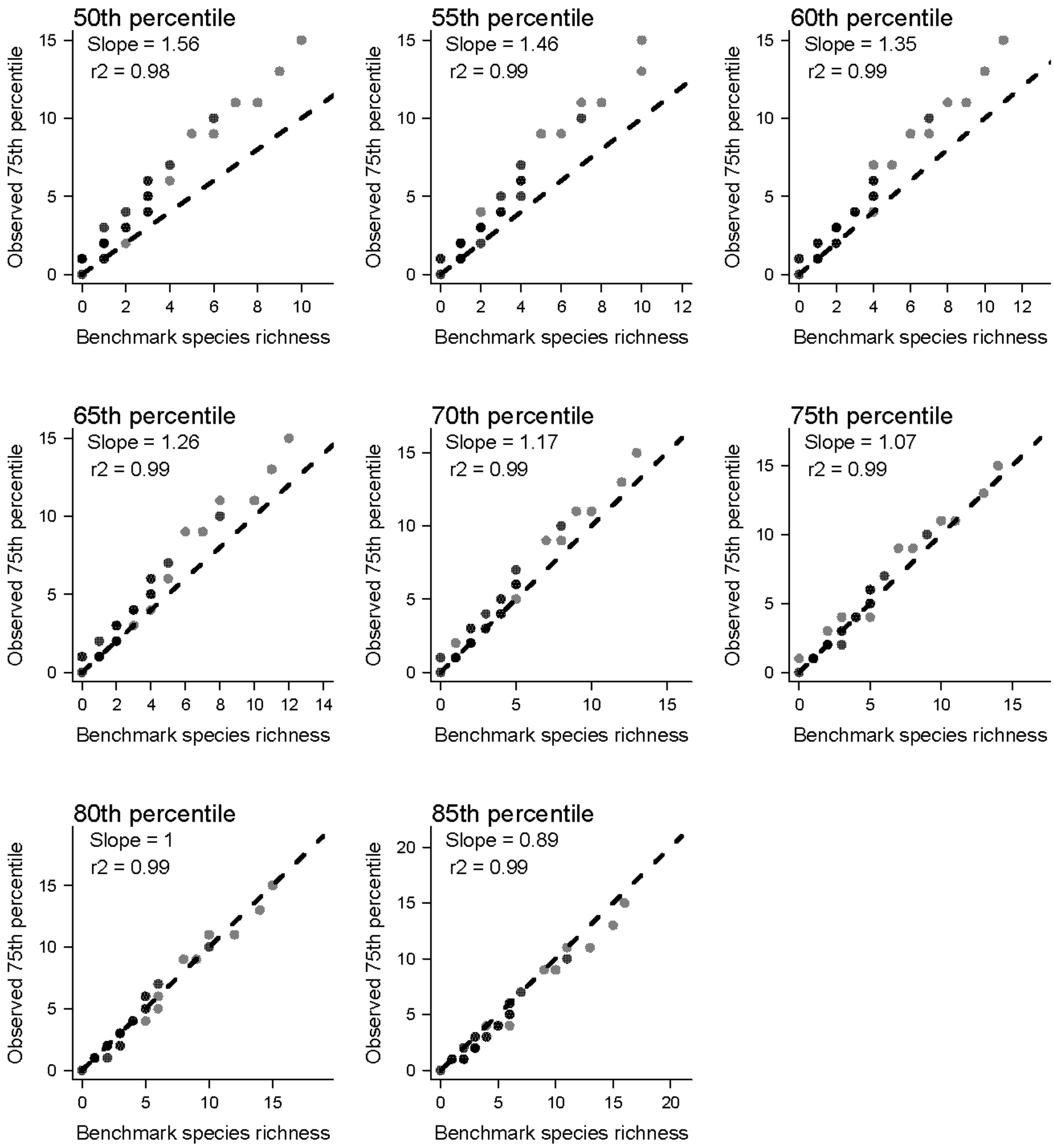

Figure 29 Estimated versus observed other richness percentiles for RVCs with > 200 plots

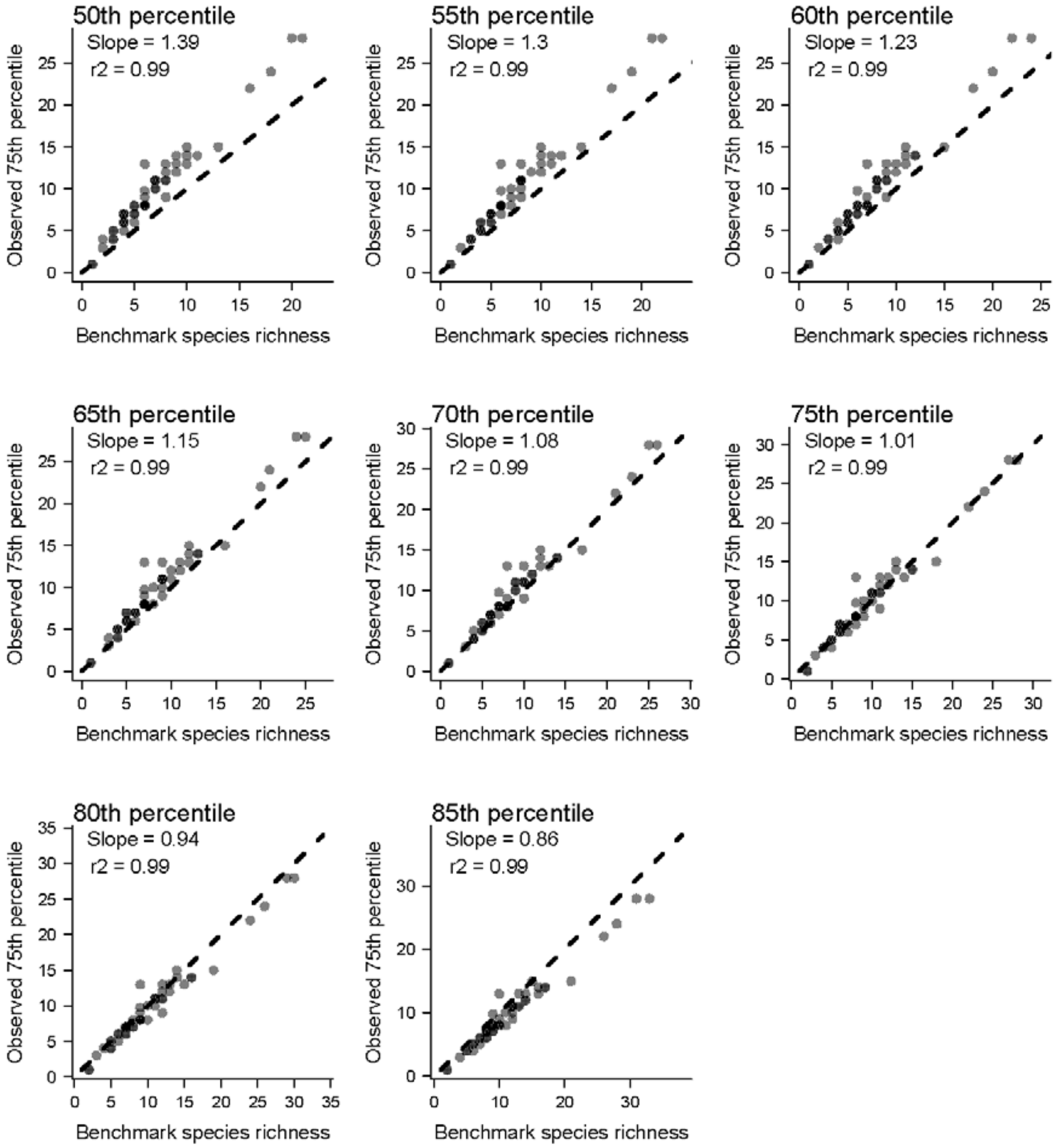

Figure 30 **Estimated versus observed shrub richness percentiles for RVCs with > 200 plots**

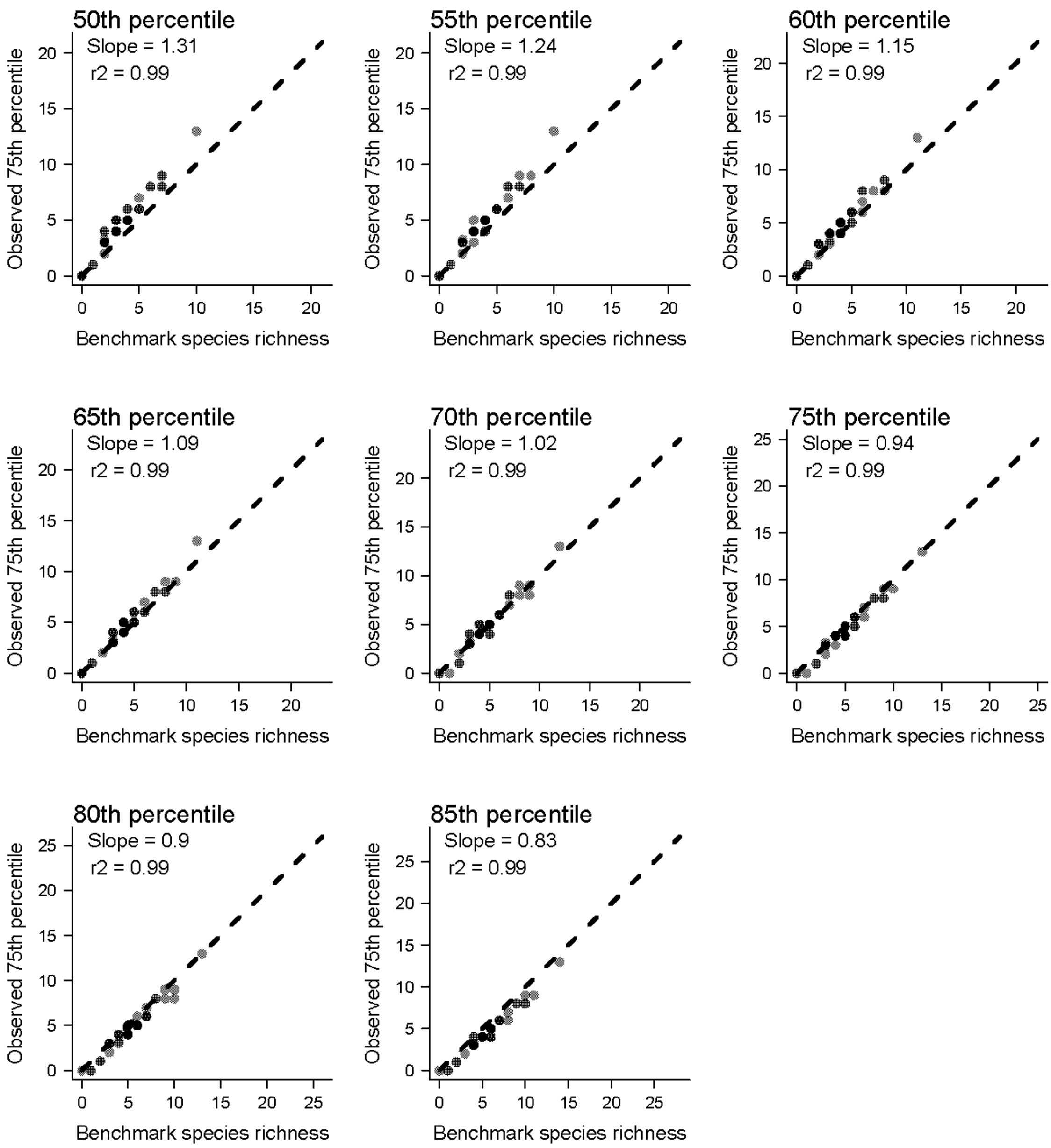

Figure 31 Estimated versus observed tree richness percentiles for RVCs with > 200 plots

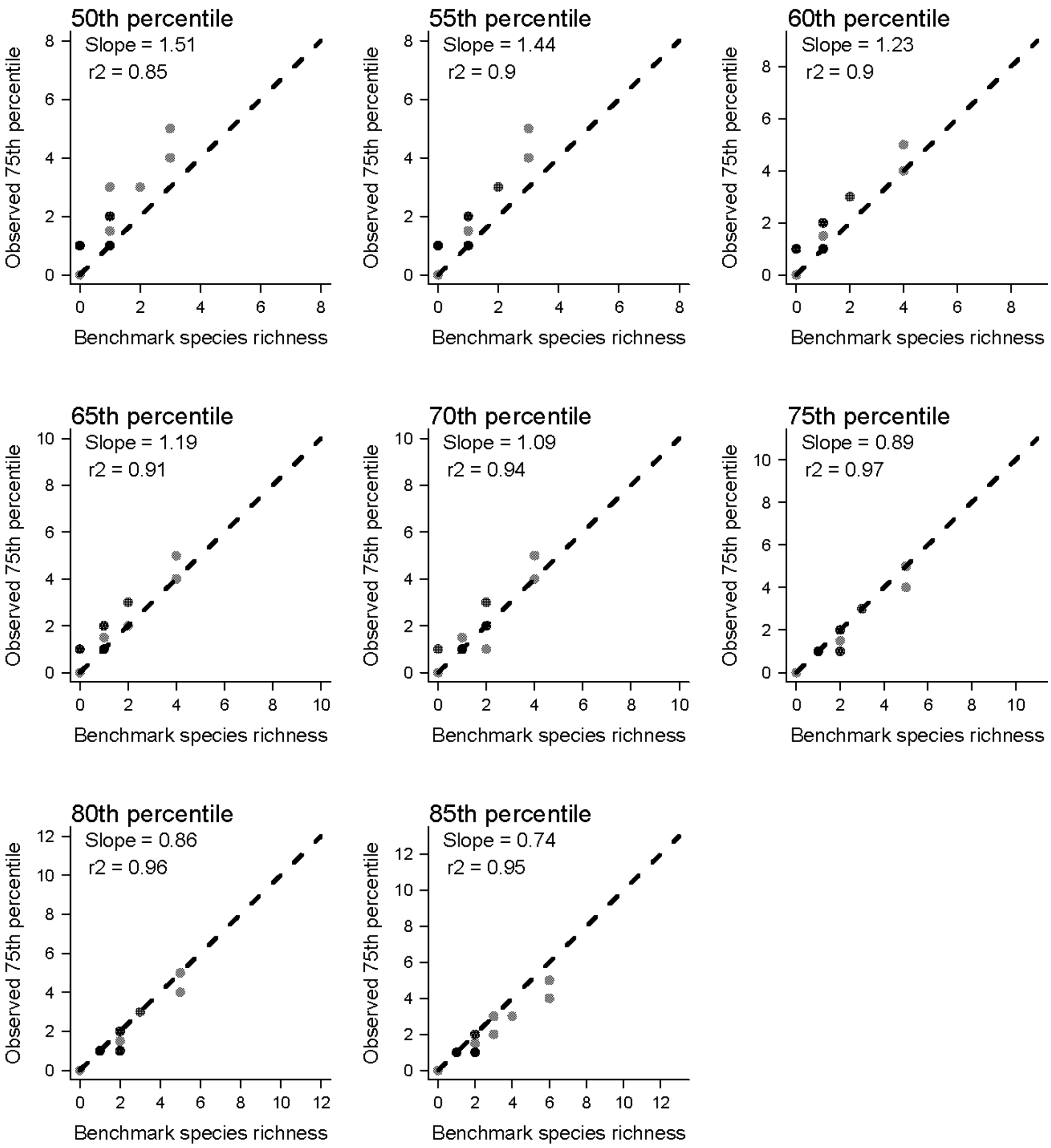

Figure 32 **Estimated versus observed fern richness percentiles for RVCs with > 300 plots**

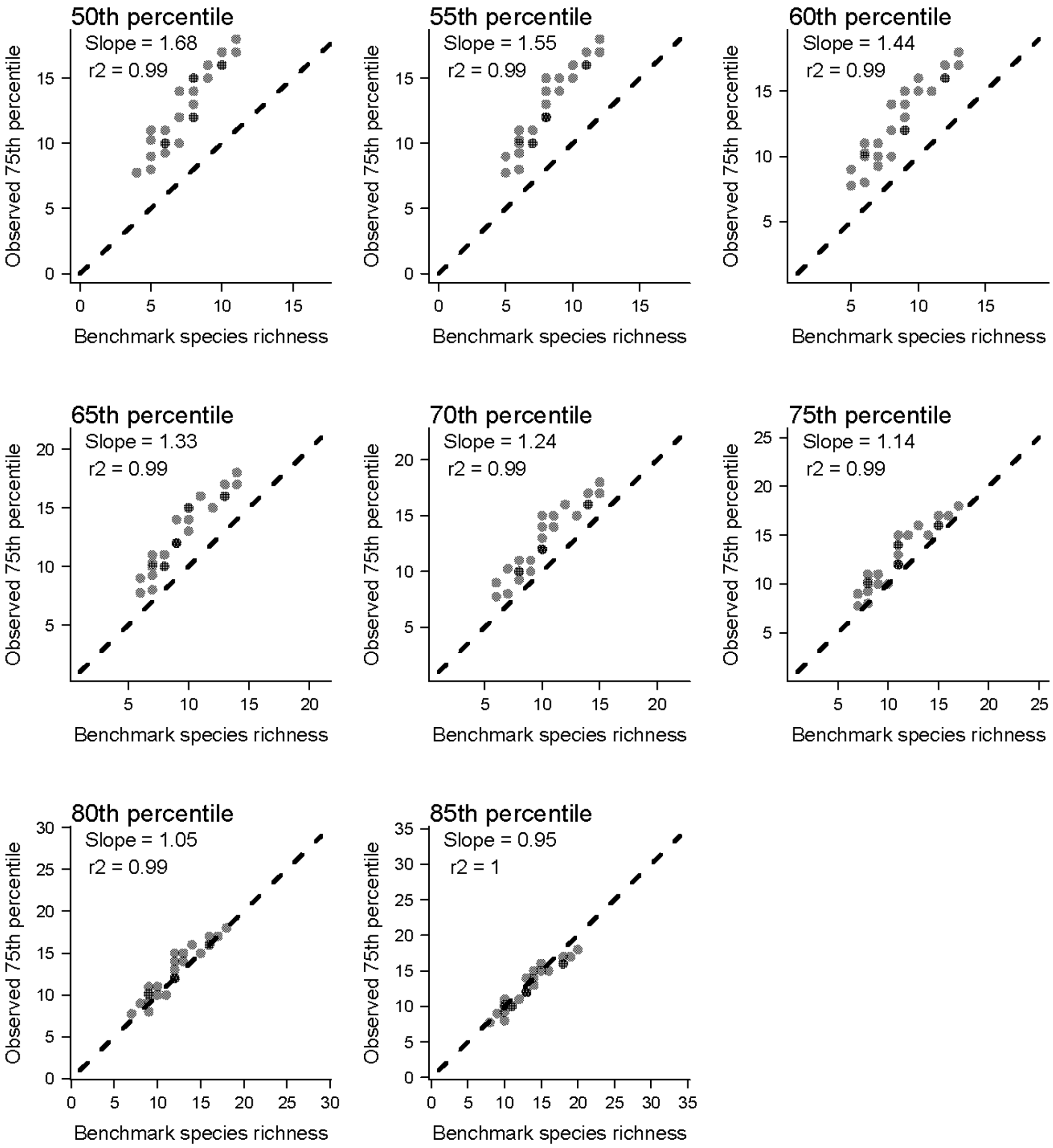

Figure 33 Estimated versus observed forb richness percentiles for RVCs with > 300 plots

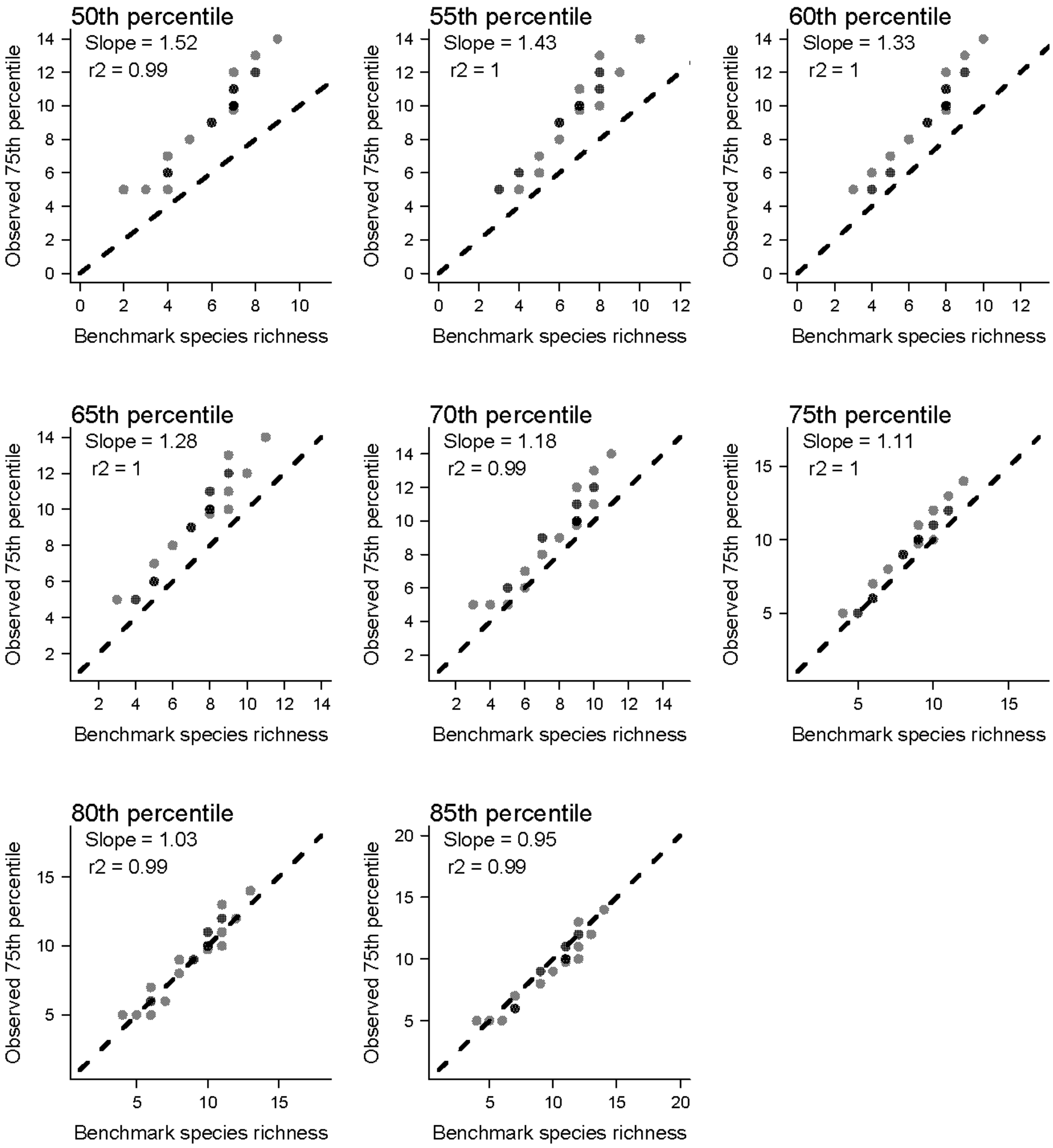

Figure 34 **Estimated versus observed grass richness percentiles for RVCs with > 300 plots**

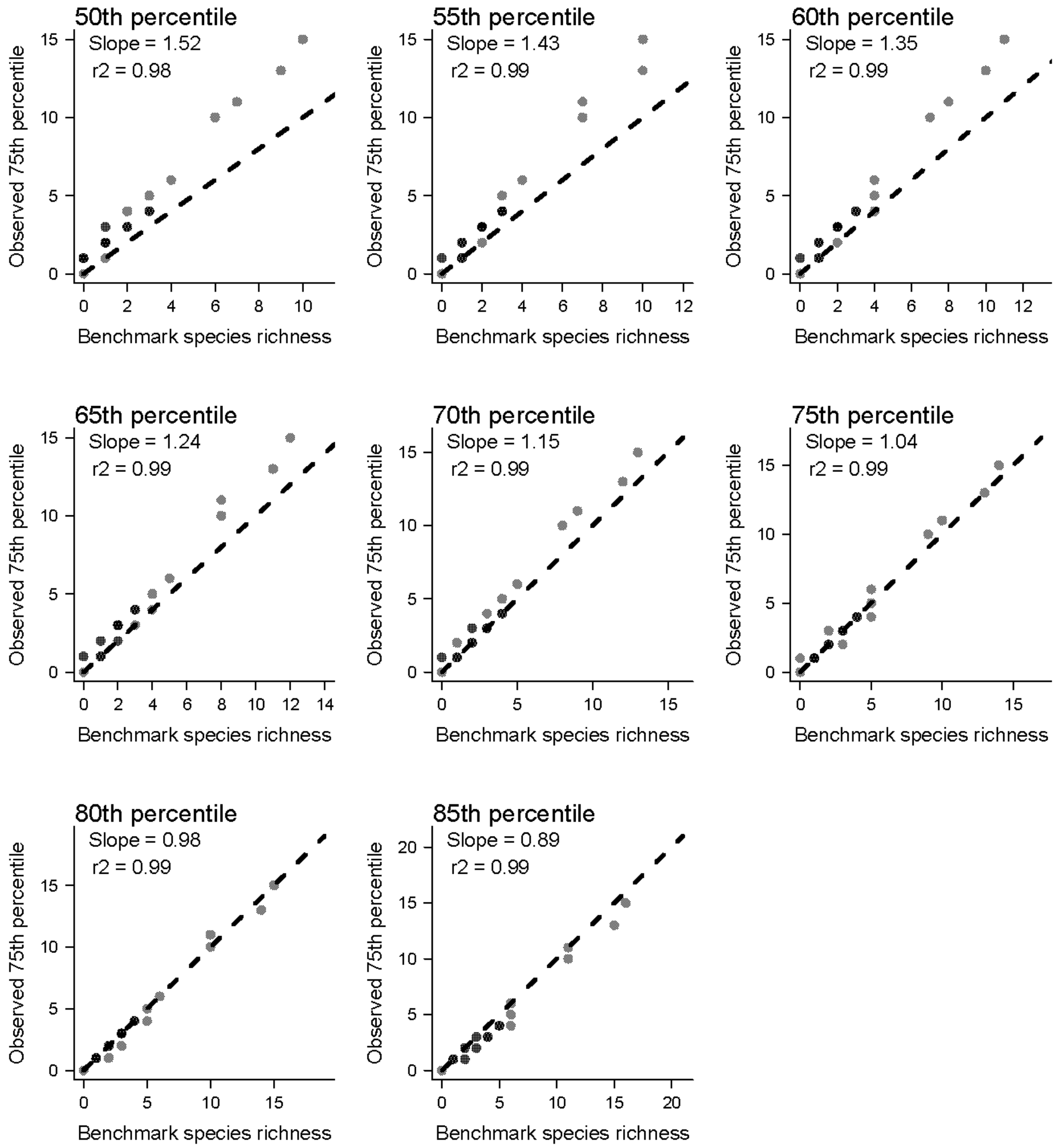

Figure 35 **Estimated versus observed other richness percentiles for RVCs with > 300 plots**

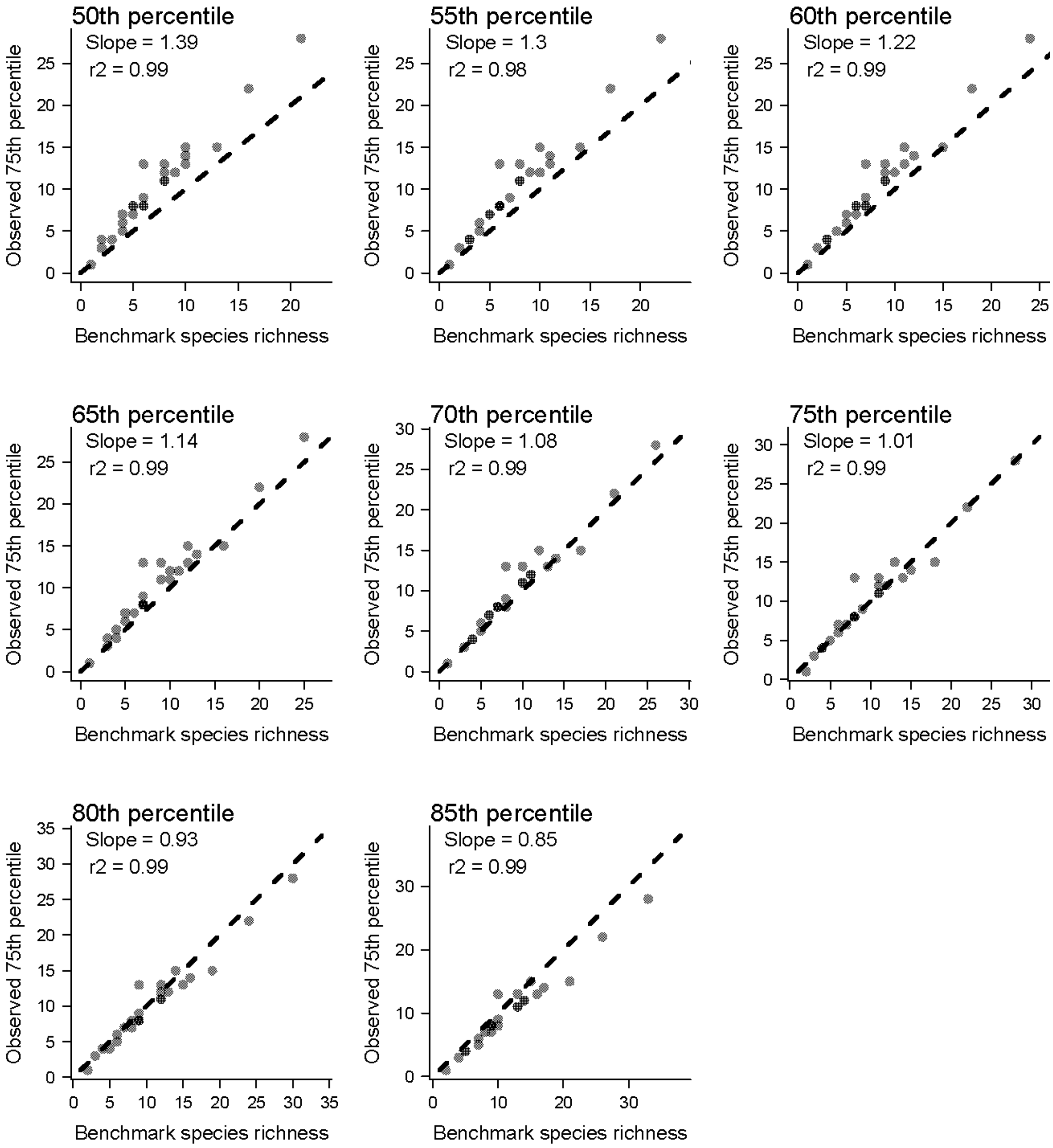

Figure 36 Estimated versus observed shrub richness percentiles for RVCs with > 300 plots

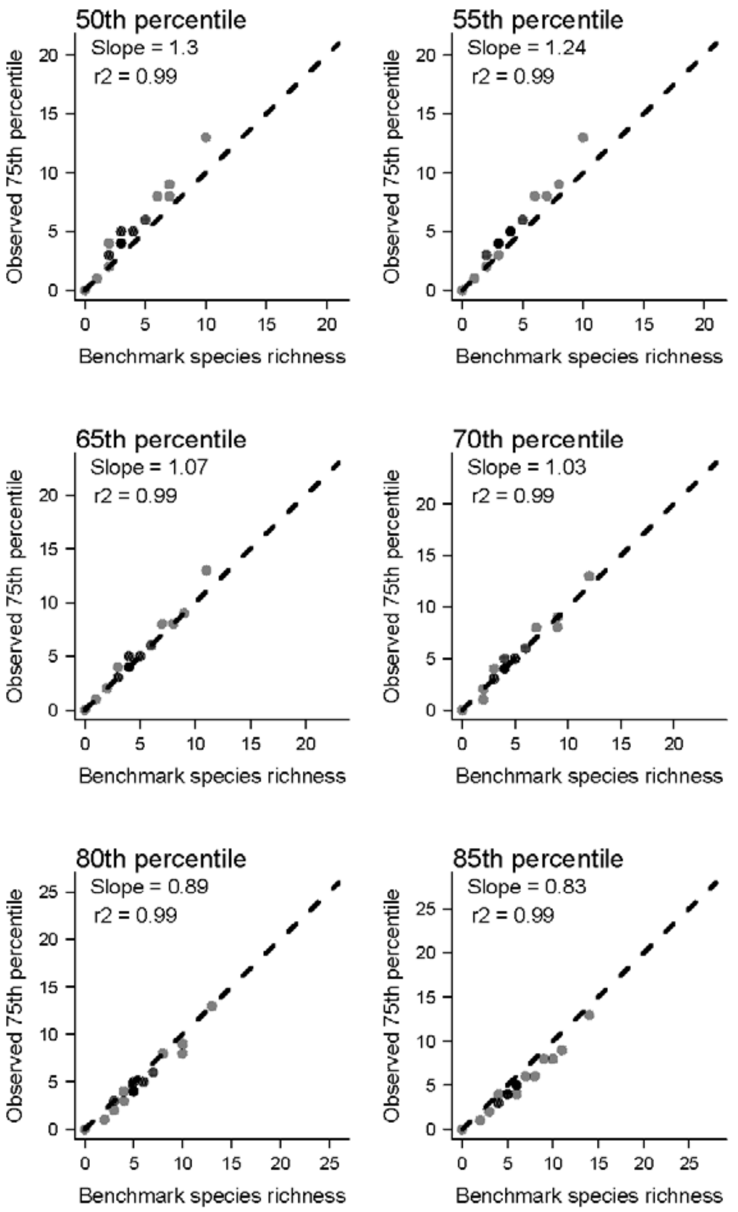

Figure 37 Estimated versus observed tree richness percentiles for RVCs with > 300 plots

Appendix 2 – Evaluation of structure benchmarks

Plots of estimated (capped) species summed cover benchmarks (from 50th to 85th percentile) against observed 75th percentiles for each Regional Vegetation Class (RVC) (dashed lines show 1:1 relationship)

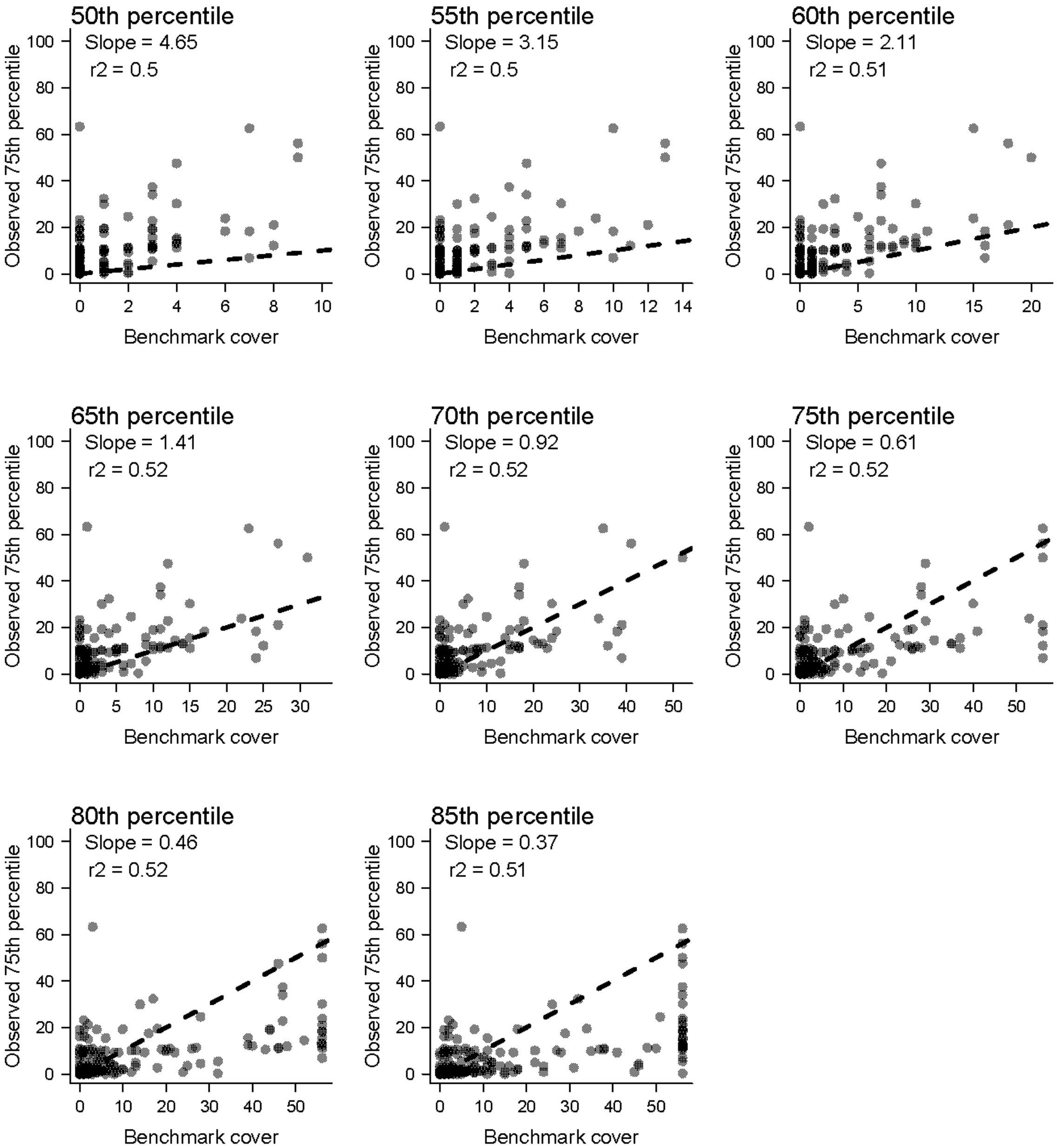

Figure 38 **Estimated versus observed fern summed cover percentiles for RVCs with > 0 plots**

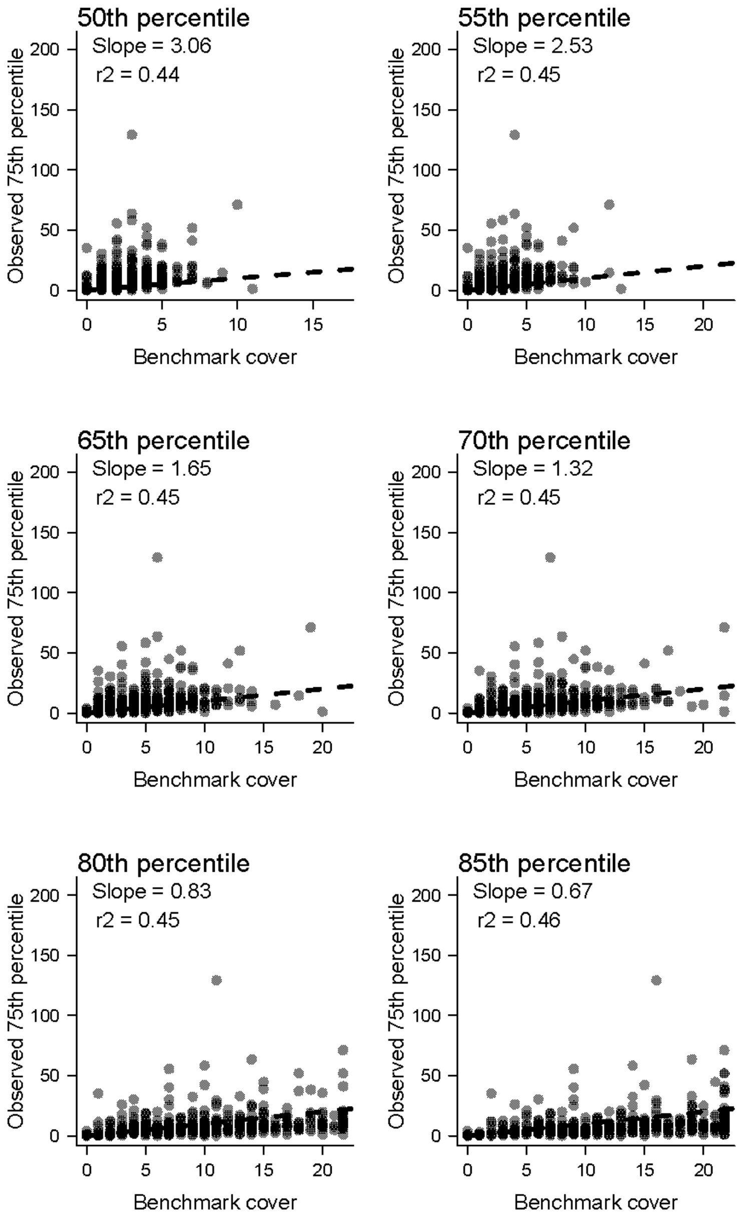

Figure 39 **Estimated versus observed forb summed cover percentiles for RVCs with > 0 plots**

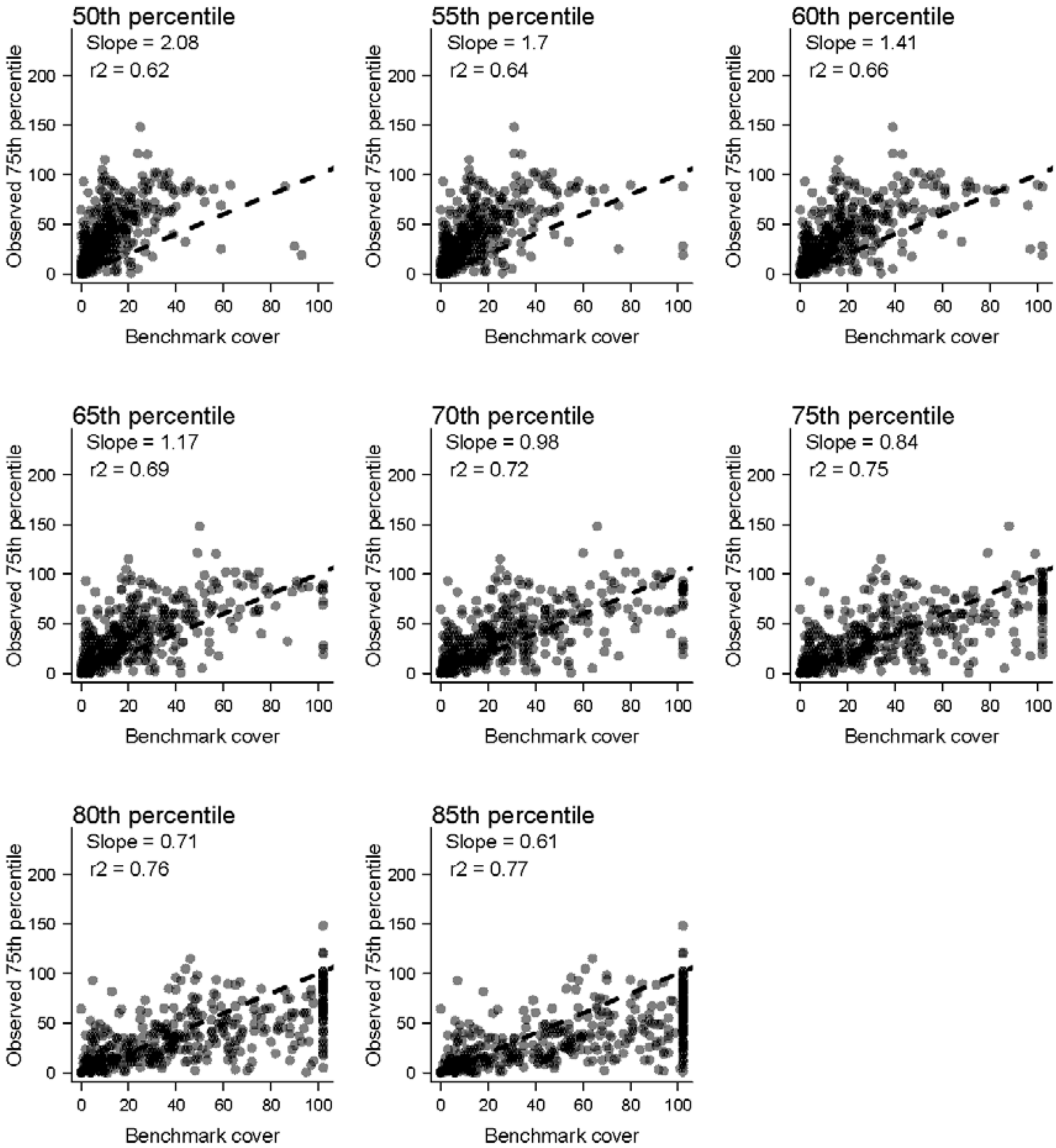

Figure 40 **Estimated versus observed grass summed cover percentiles for RVCs with > 0 plots**

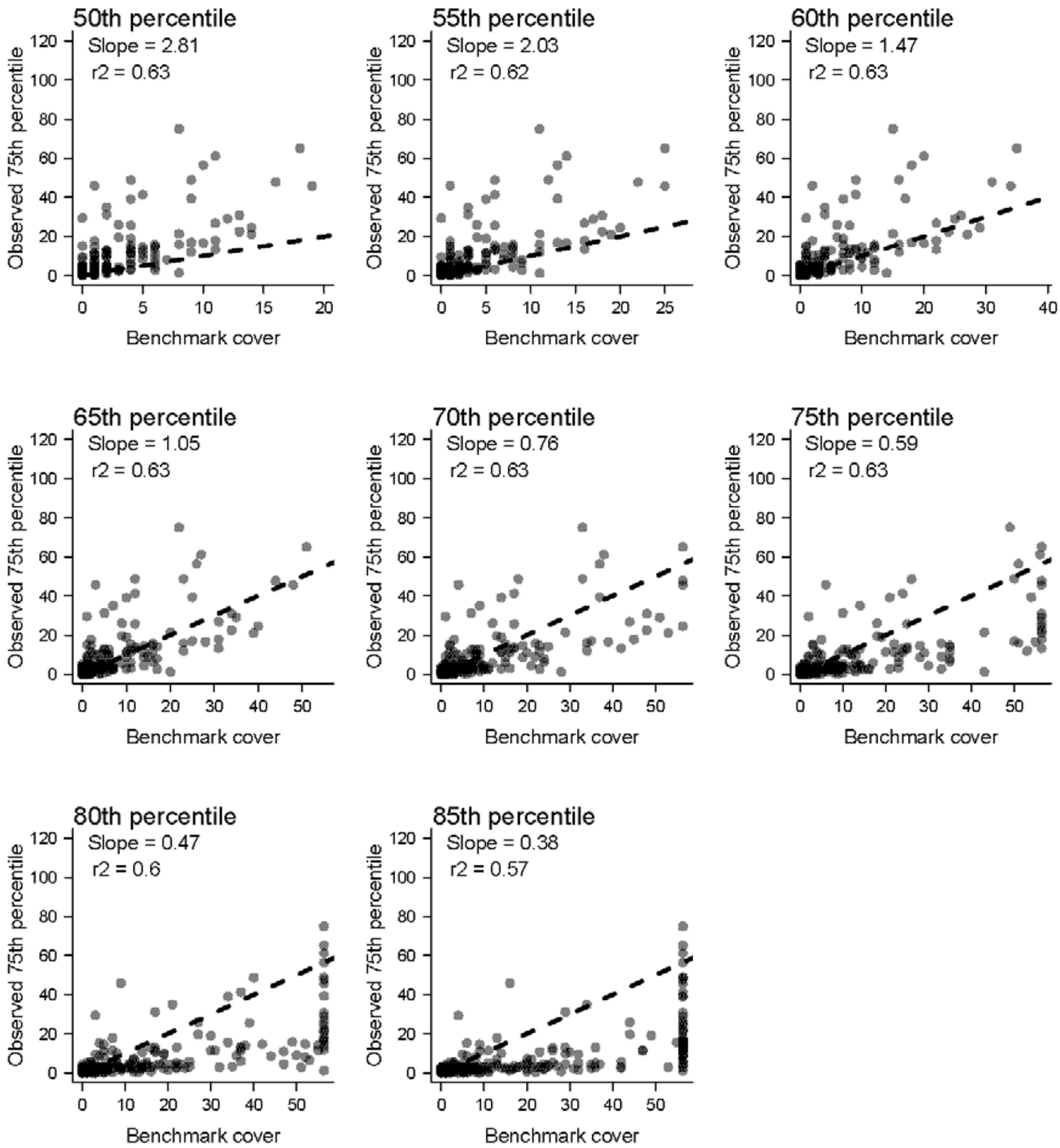

Figure 41 Estimated versus observed other summed cover percentiles for RVCs with > 0 plots

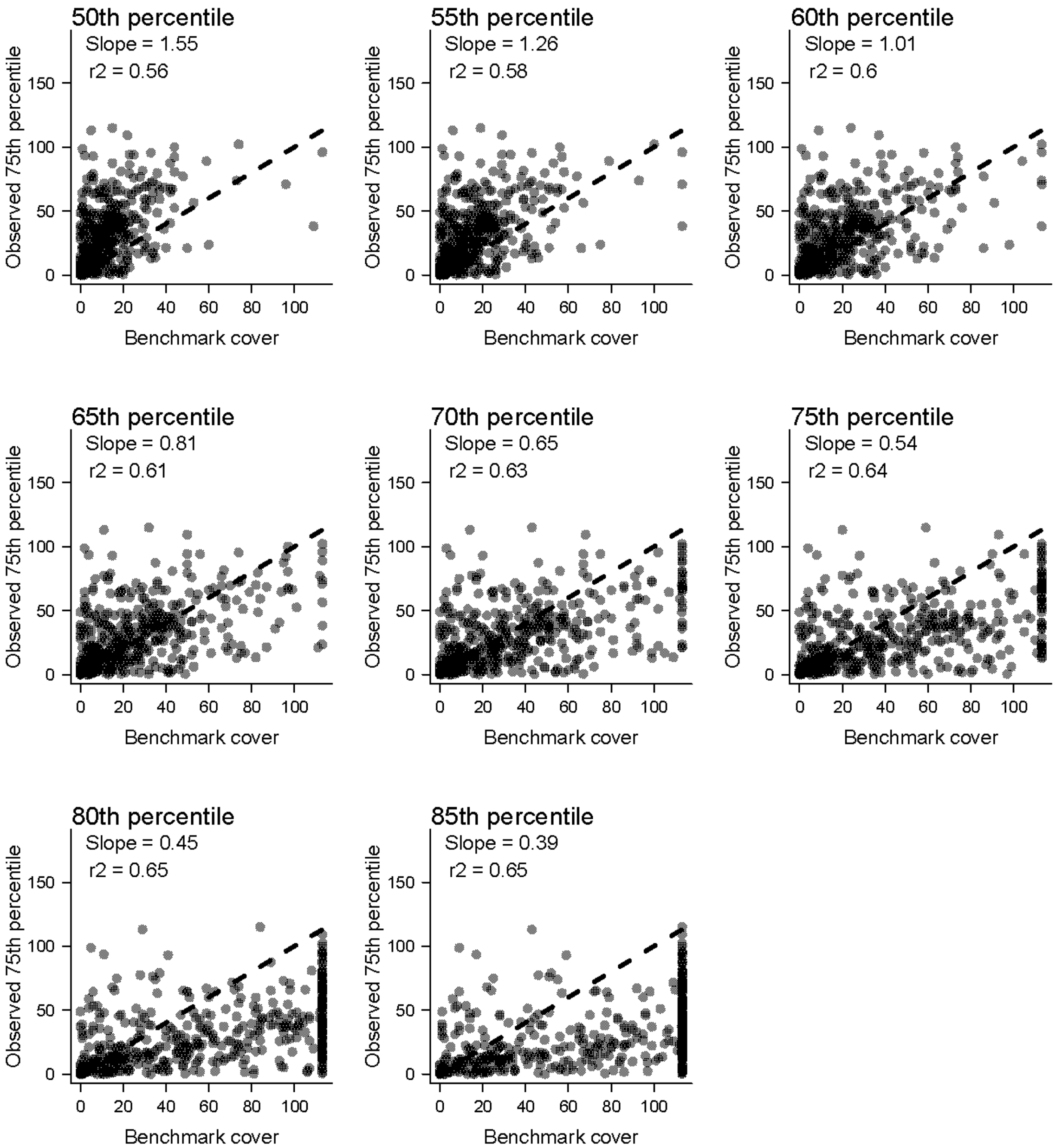

Figure 42 **Estimated versus observed shrub summed cover percentiles for RVCs with > 0 plots**

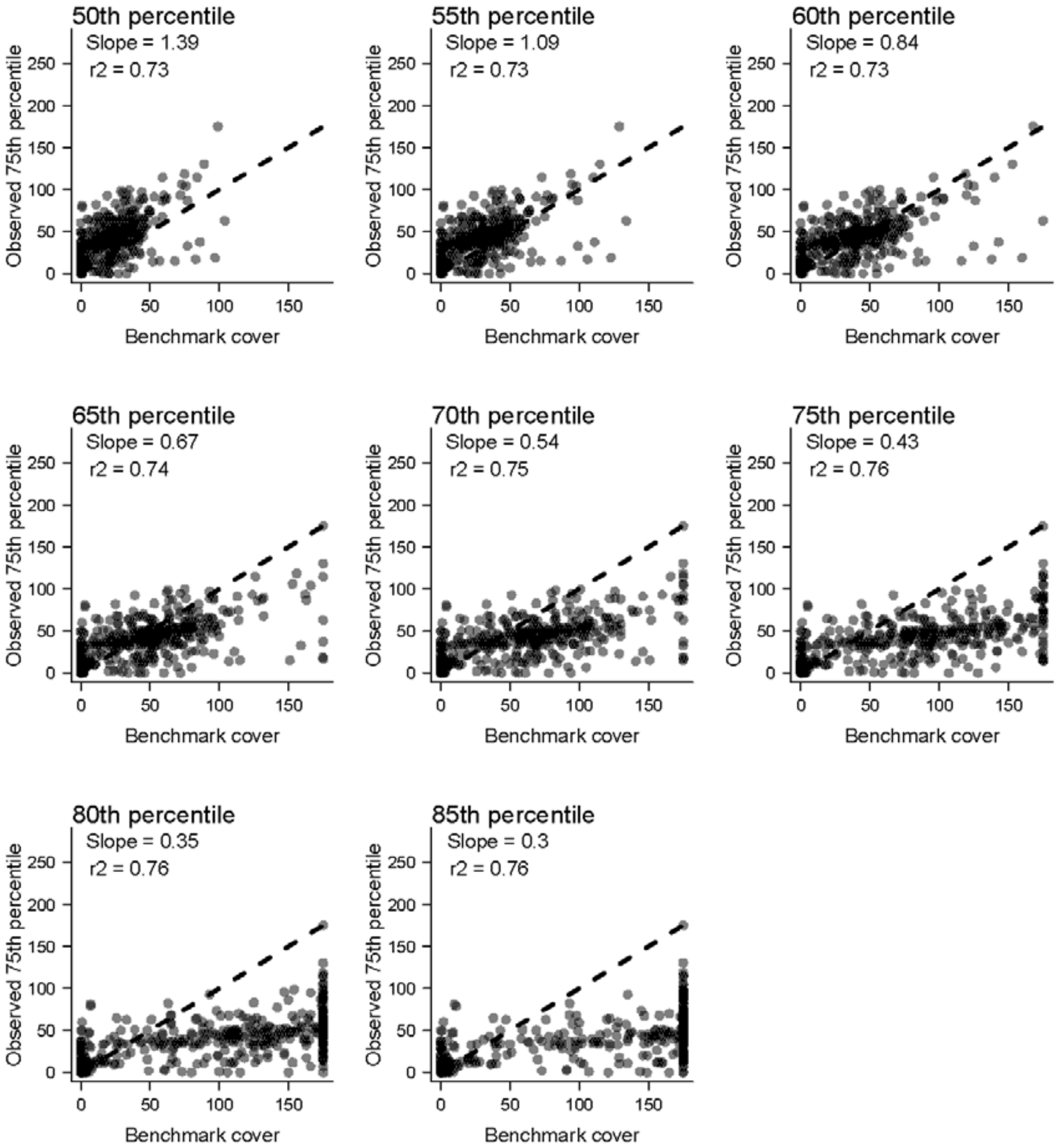

Figure 43 **Estimated versus observed tree summed cover percentiles for RVCs with > 0 plots**

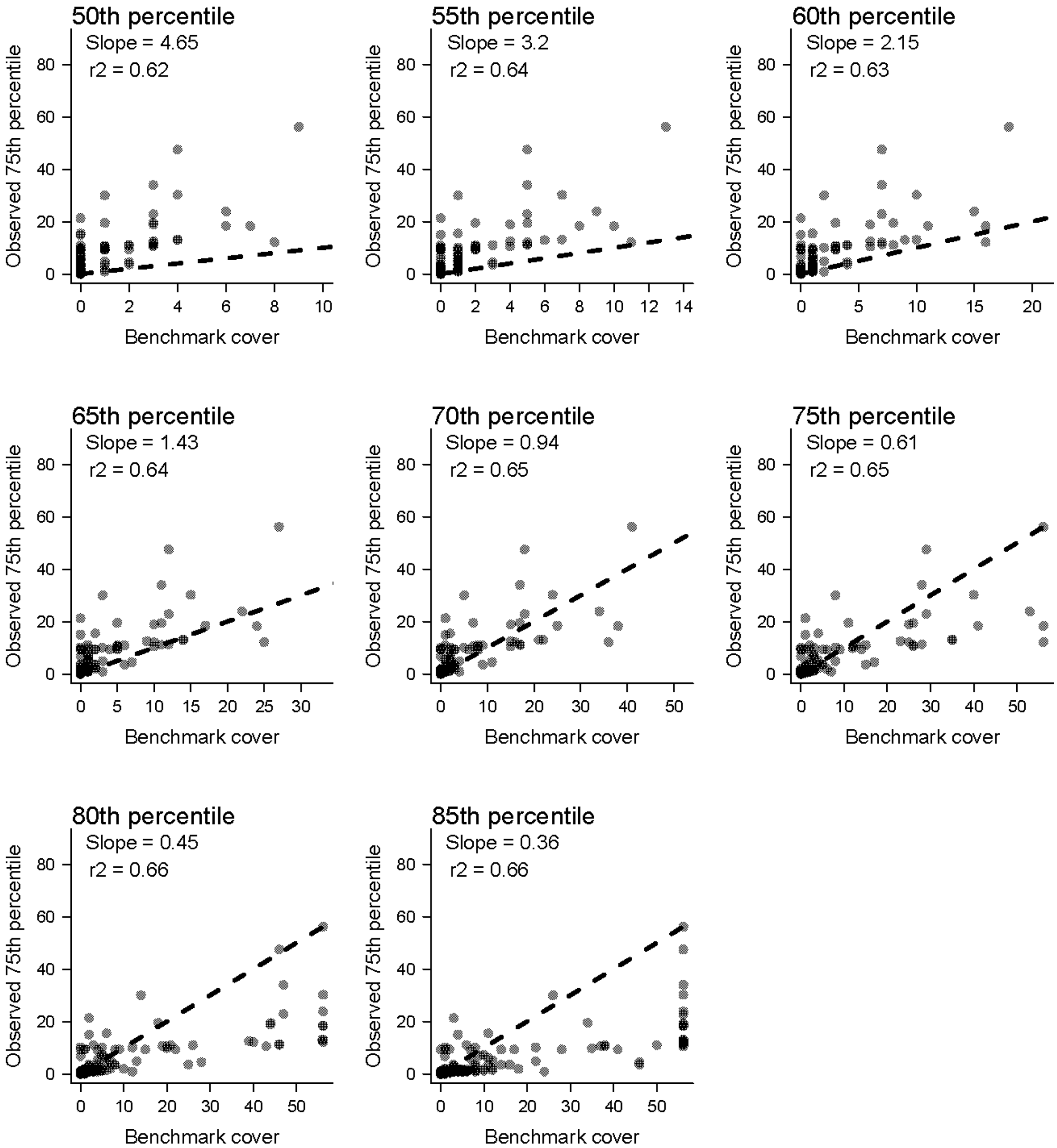

Figure 44 **Estimated versus observed fern summed cover percentiles for RVCs with > 20 plots**

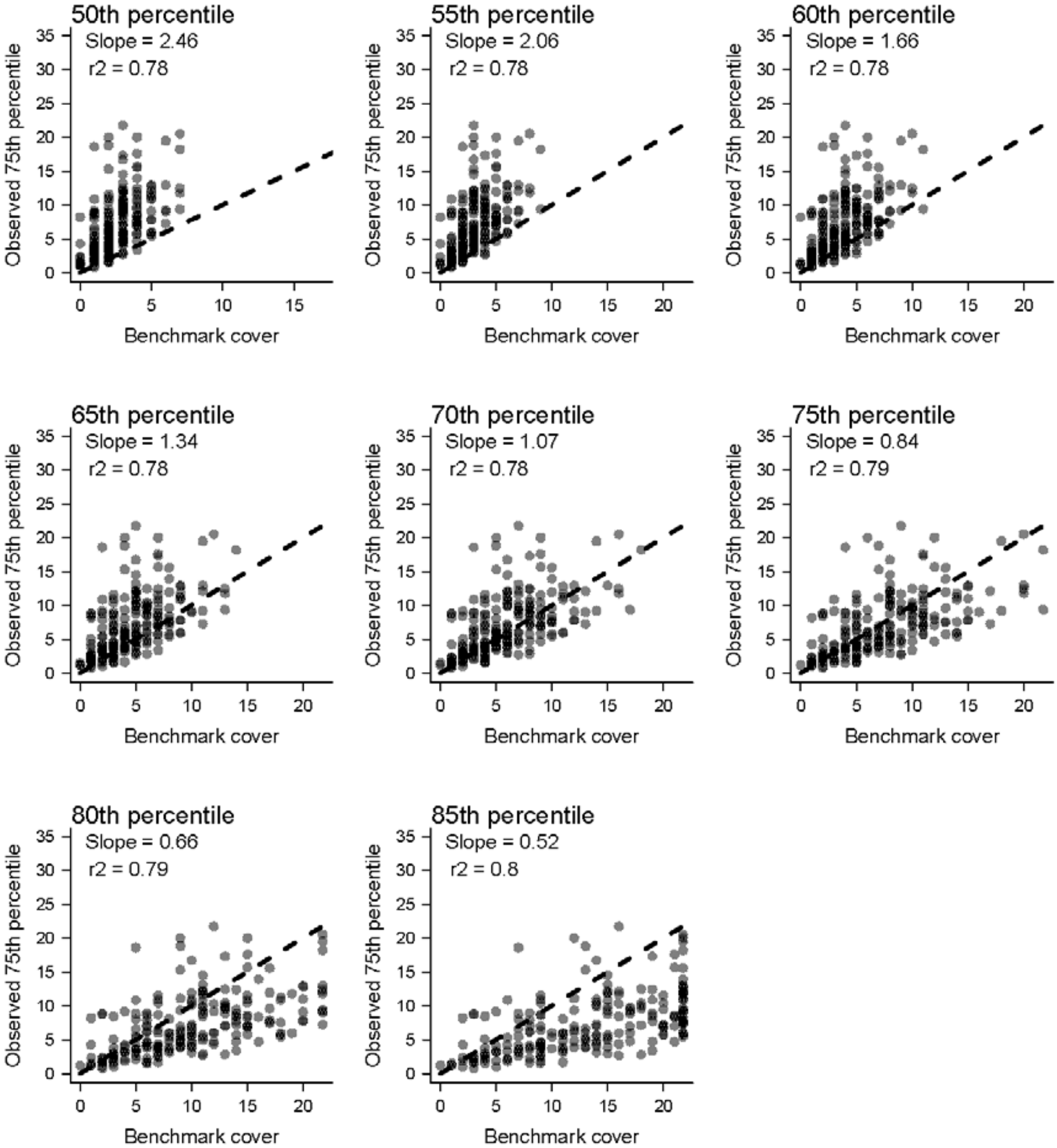

Figure 45 **Estimated versus observed forb summed cover percentiles for RVCs with > 20 plots**

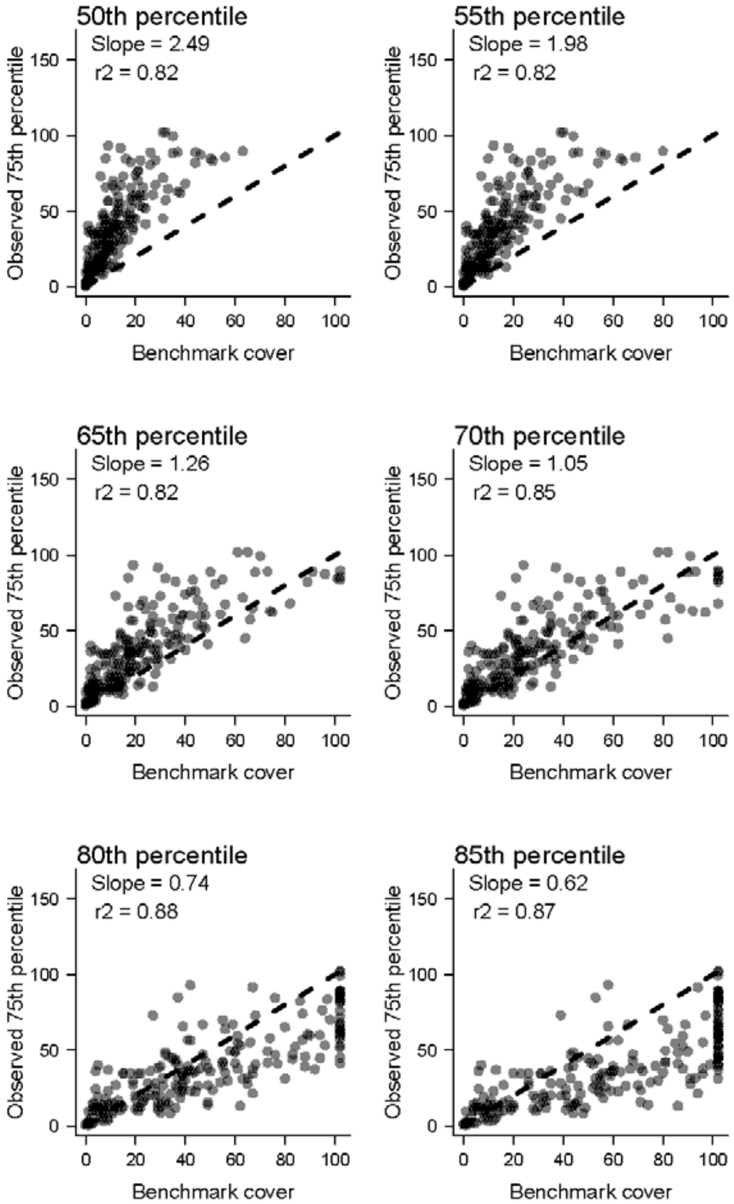

Figure 46 **Estimated versus observed grass summed cover percentiles for RVCs with > 20 plots**

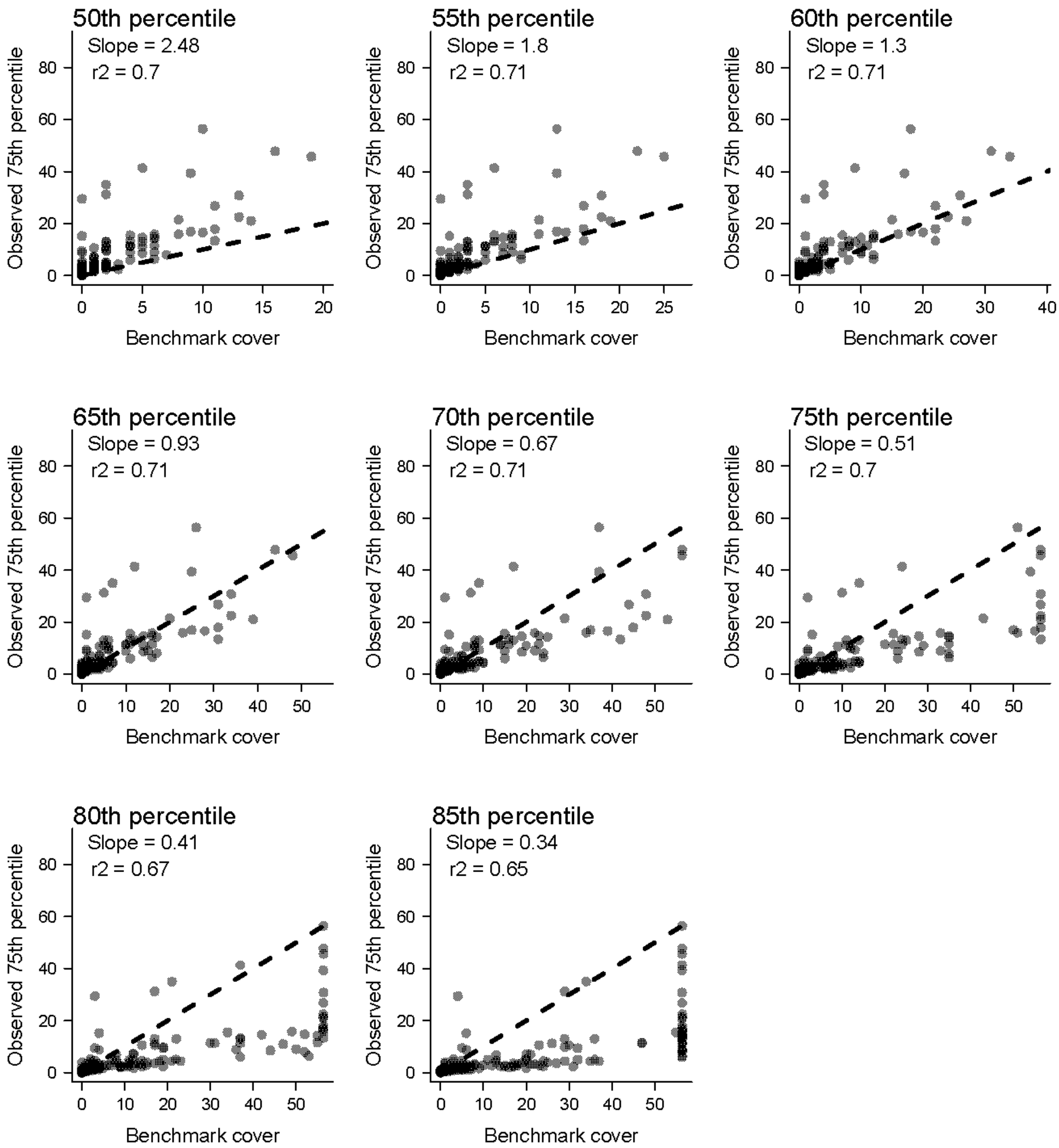

Figure 47 Estimated versus observed other summed cover percentiles for RVCs with > 20 plots

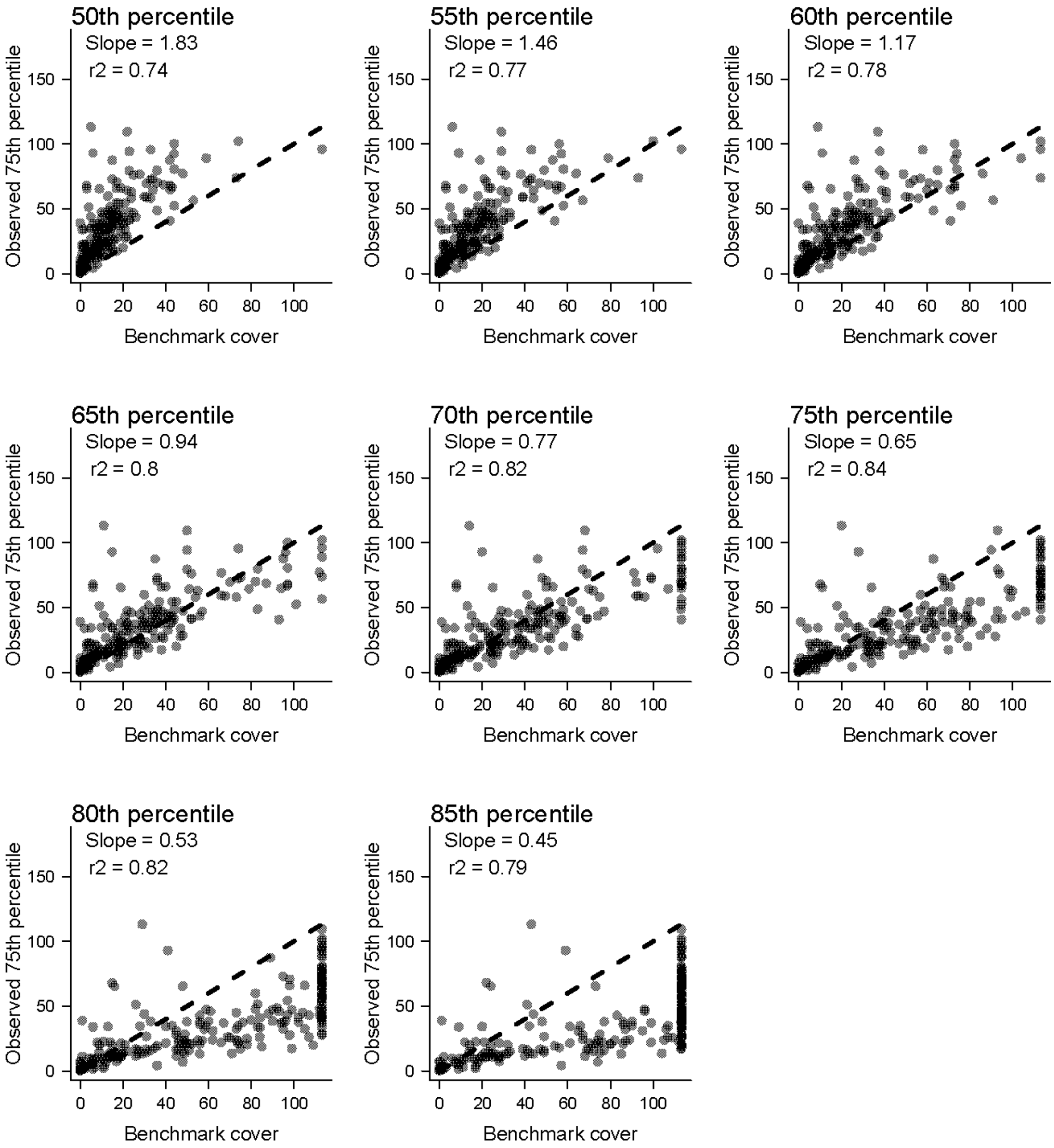

Figure 48 **Estimated versus observed shrub summed cover percentiles for RVCs with > 20 plots**

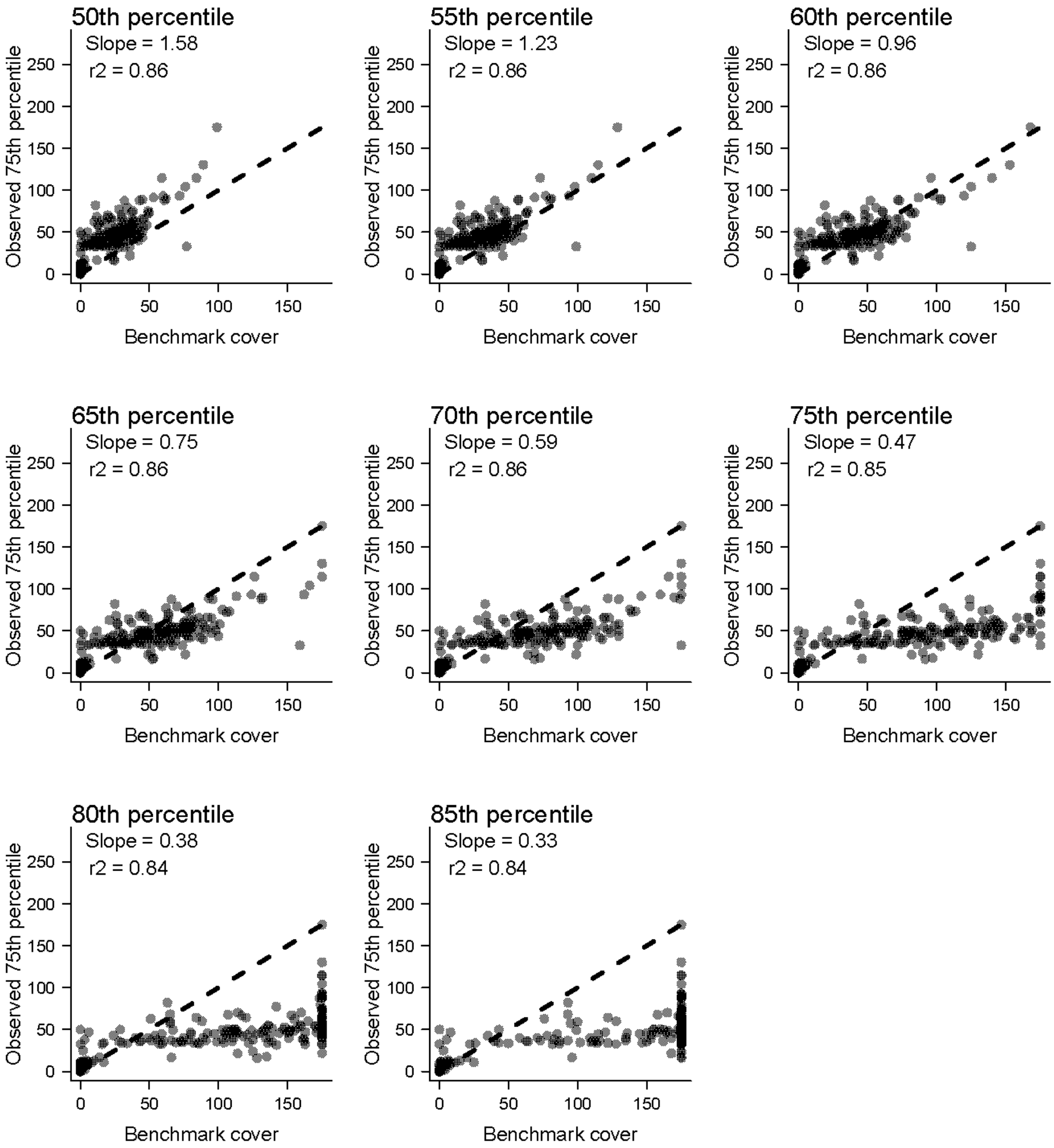

Figure 49 **Estimated versus observed tree summed cover percentiles for RVCs with > 20 plots**

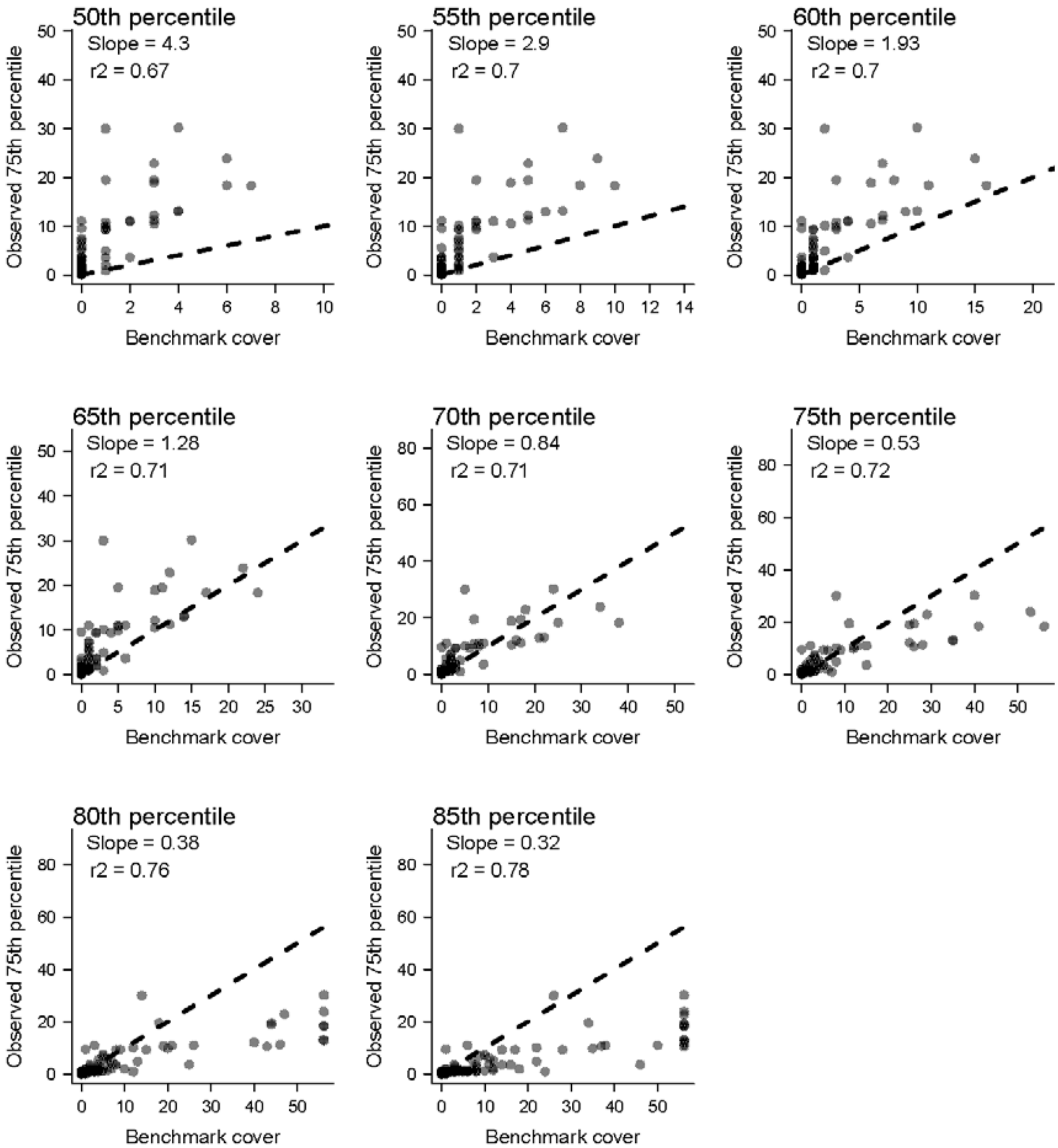

Figure 50 **Estimated versus observed fern summed cover percentiles for RVCs with > 50 plots**

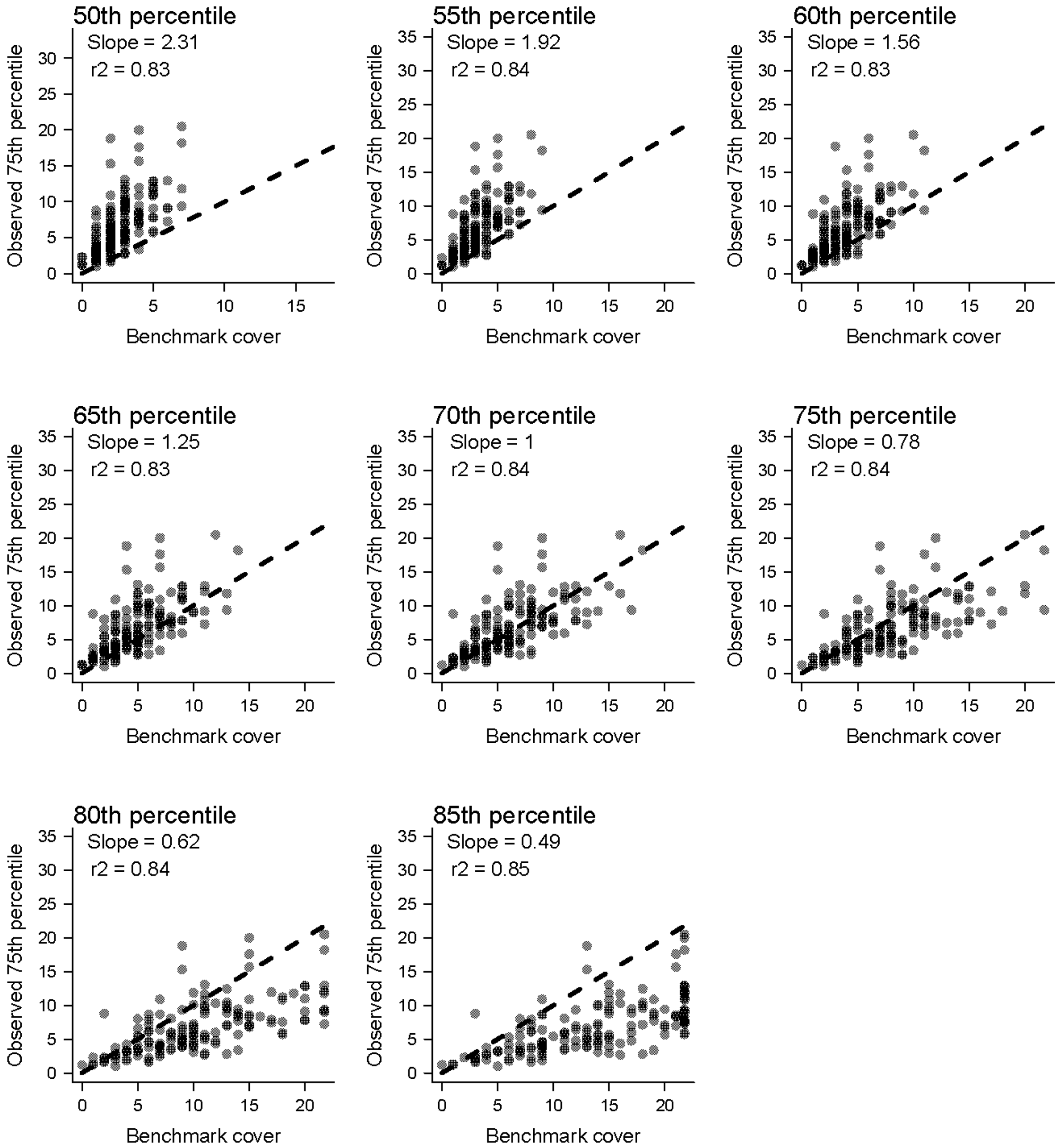

Figure 51 **Estimated versus observed forb summed cover percentiles for RVCs with > 50 plots**

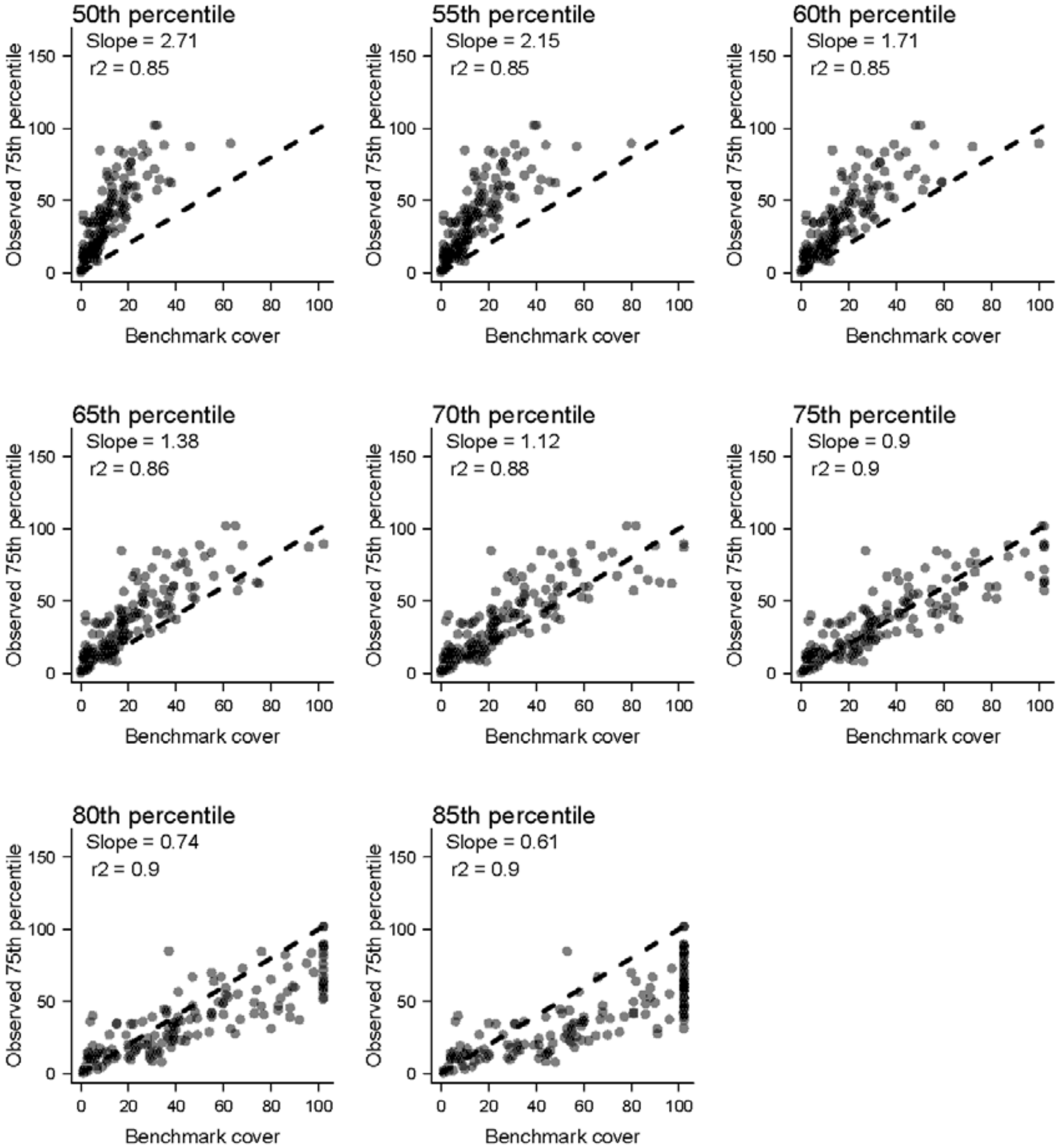

Figure 52 **Estimated versus observed grass summed cover percentiles for RVCs with > 50 plots**

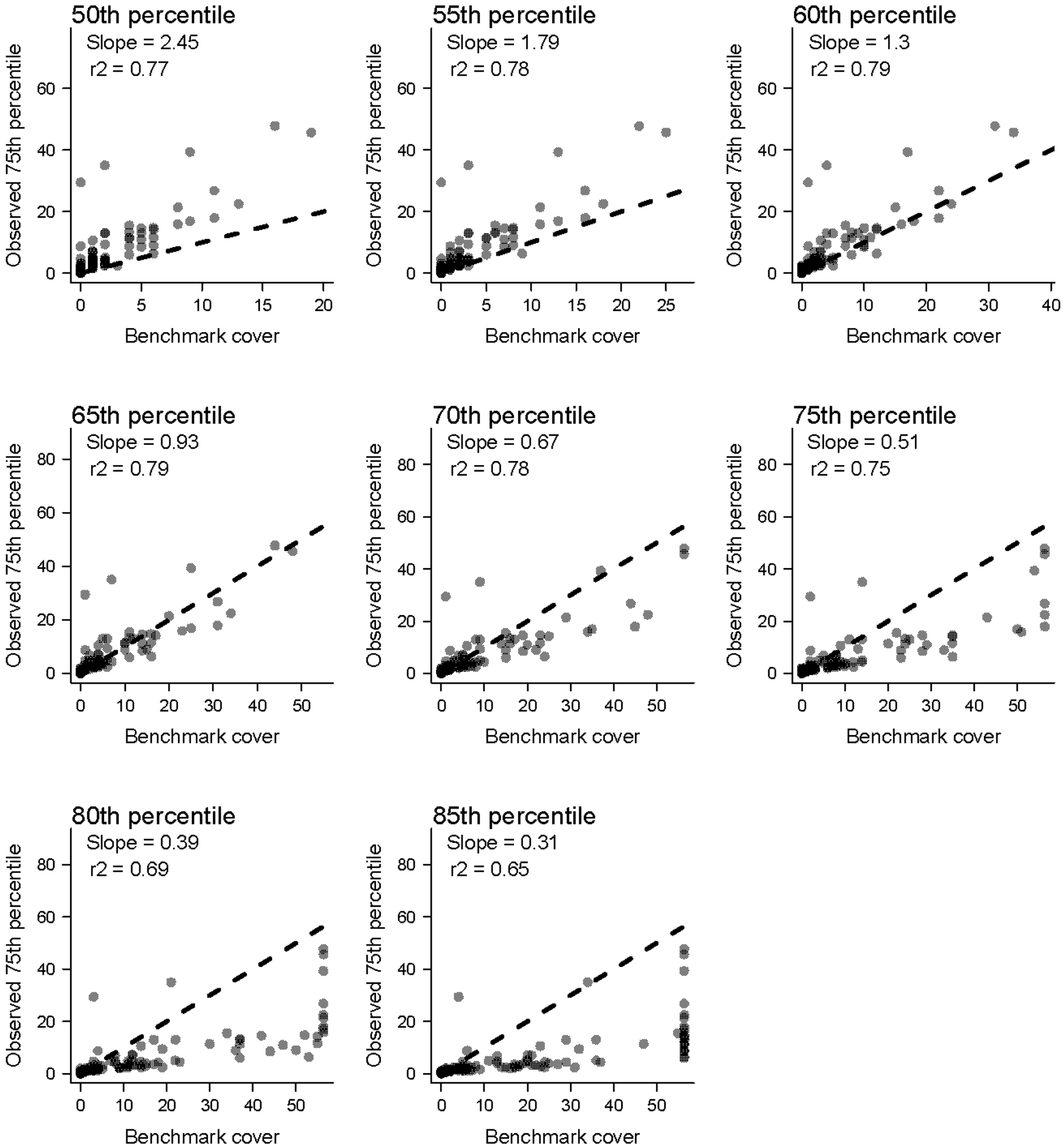

Figure 53 **Estimated versus observed other summed cover percentiles for RVCs with > 50 plots**

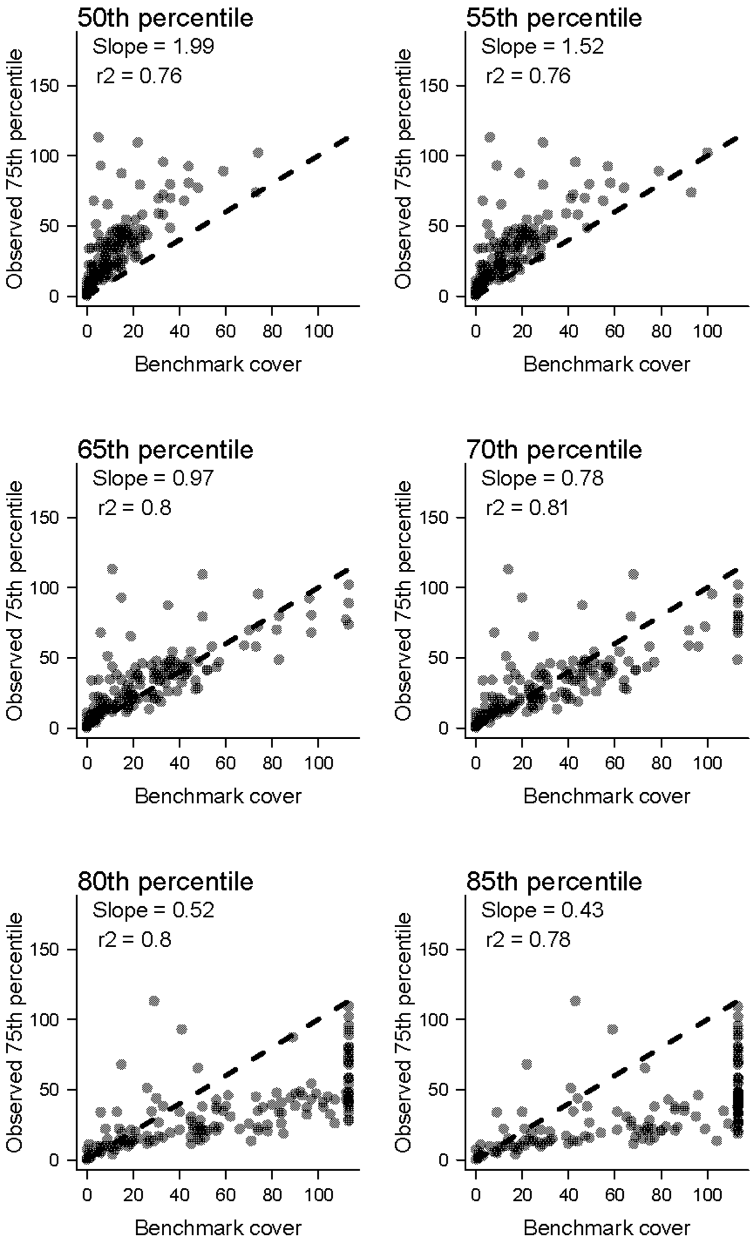

Figure 54 **Estimated versus observed shrub summed cover percentiles for RVCs with > 50 plots**

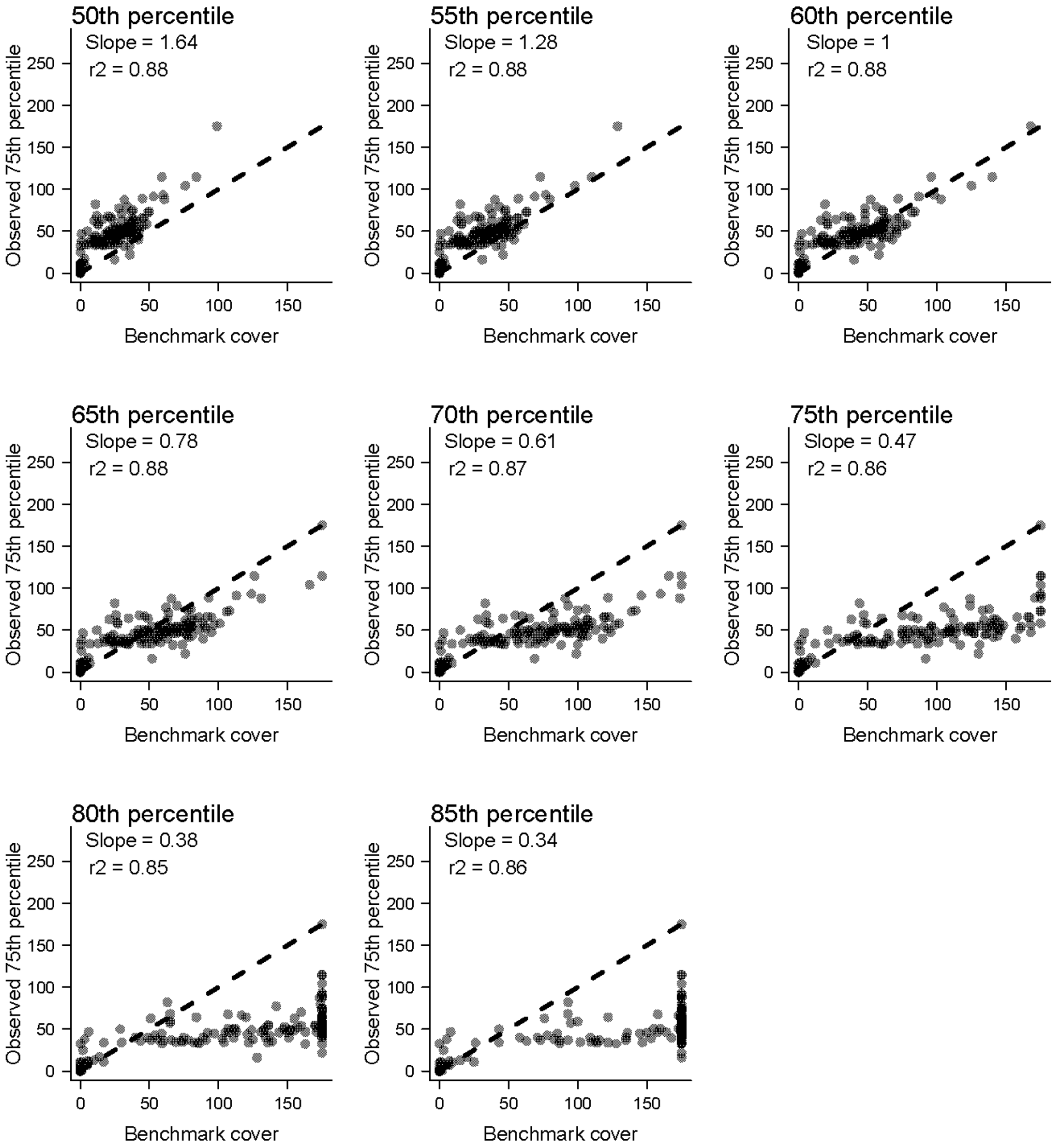

Figure 55 Estimated versus observed tree summed cover percentiles for RVCs with > 50 plots

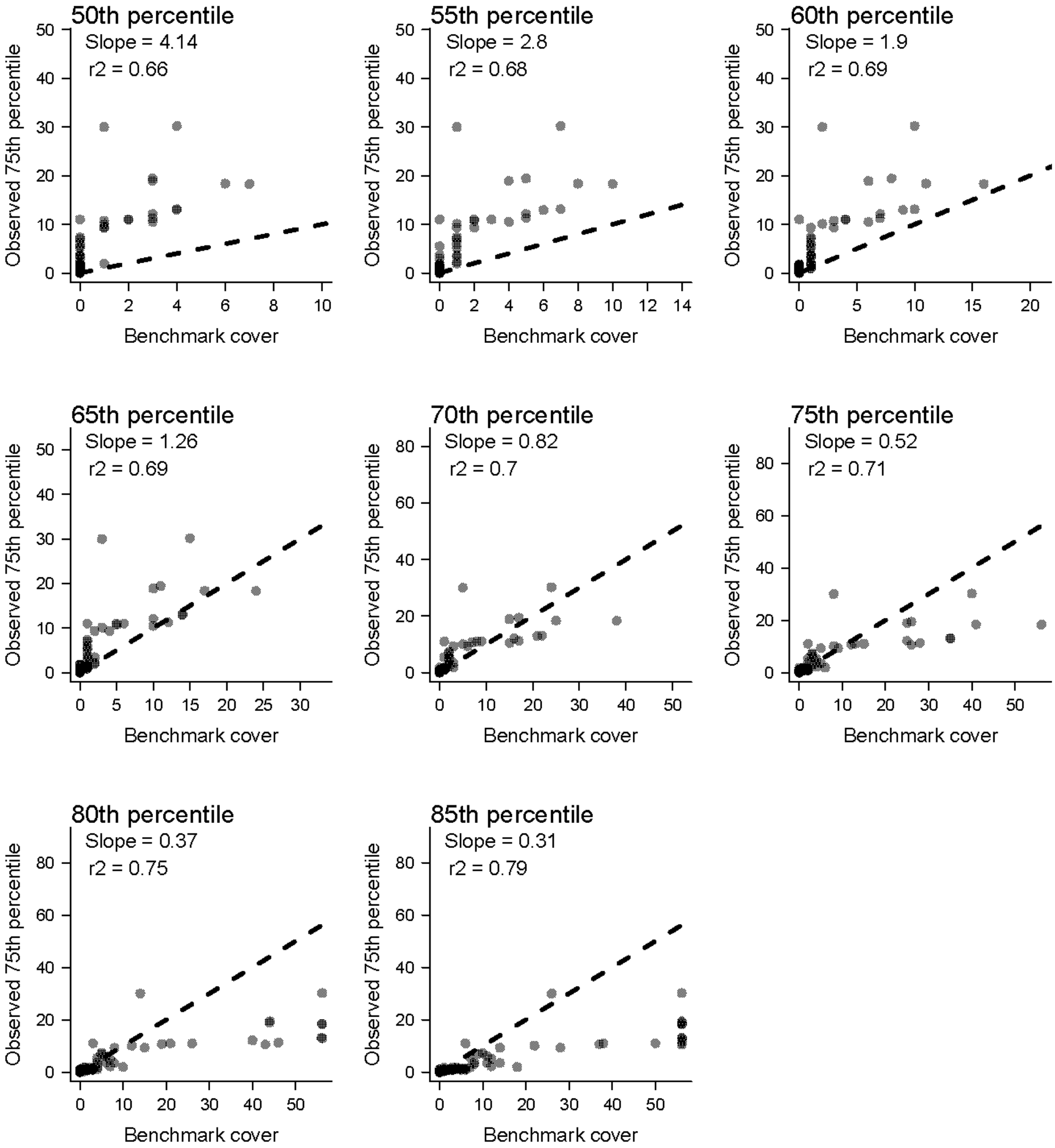

Figure 56 **Estimated versus observed fern summed cover percentiles for RVCs with > 100 plots**

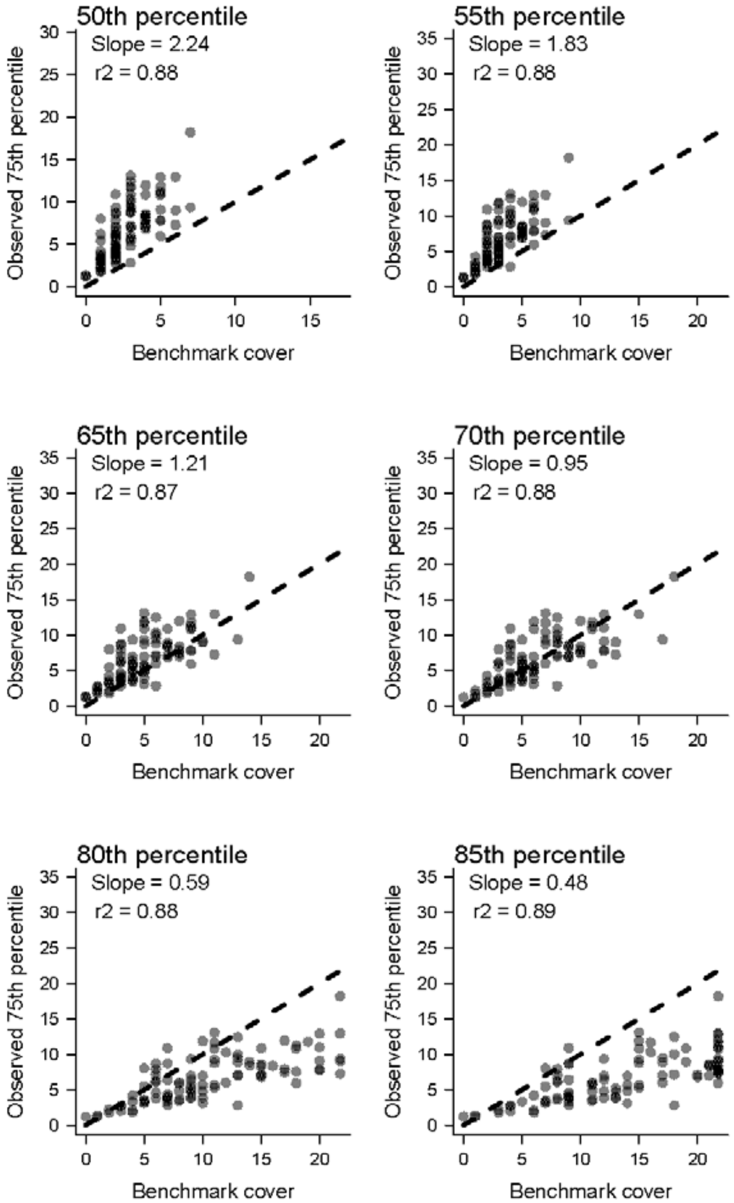

Figure 57 Estimated versus observed forb summed cover percentiles for RVCs with > 100 plots

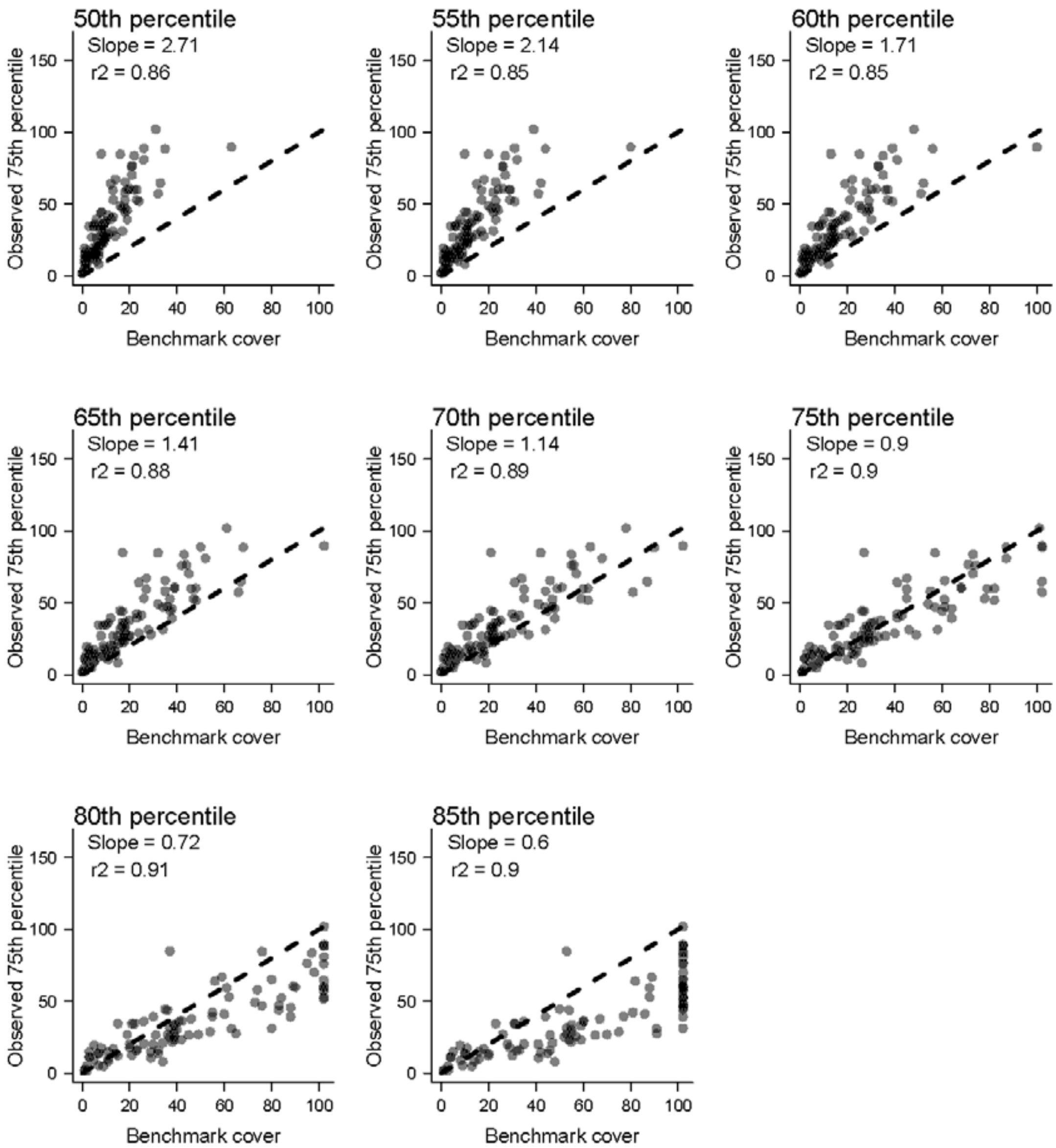

Figure 58 Estimated versus observed grass summed cover percentiles for RVCs with > 100 plots

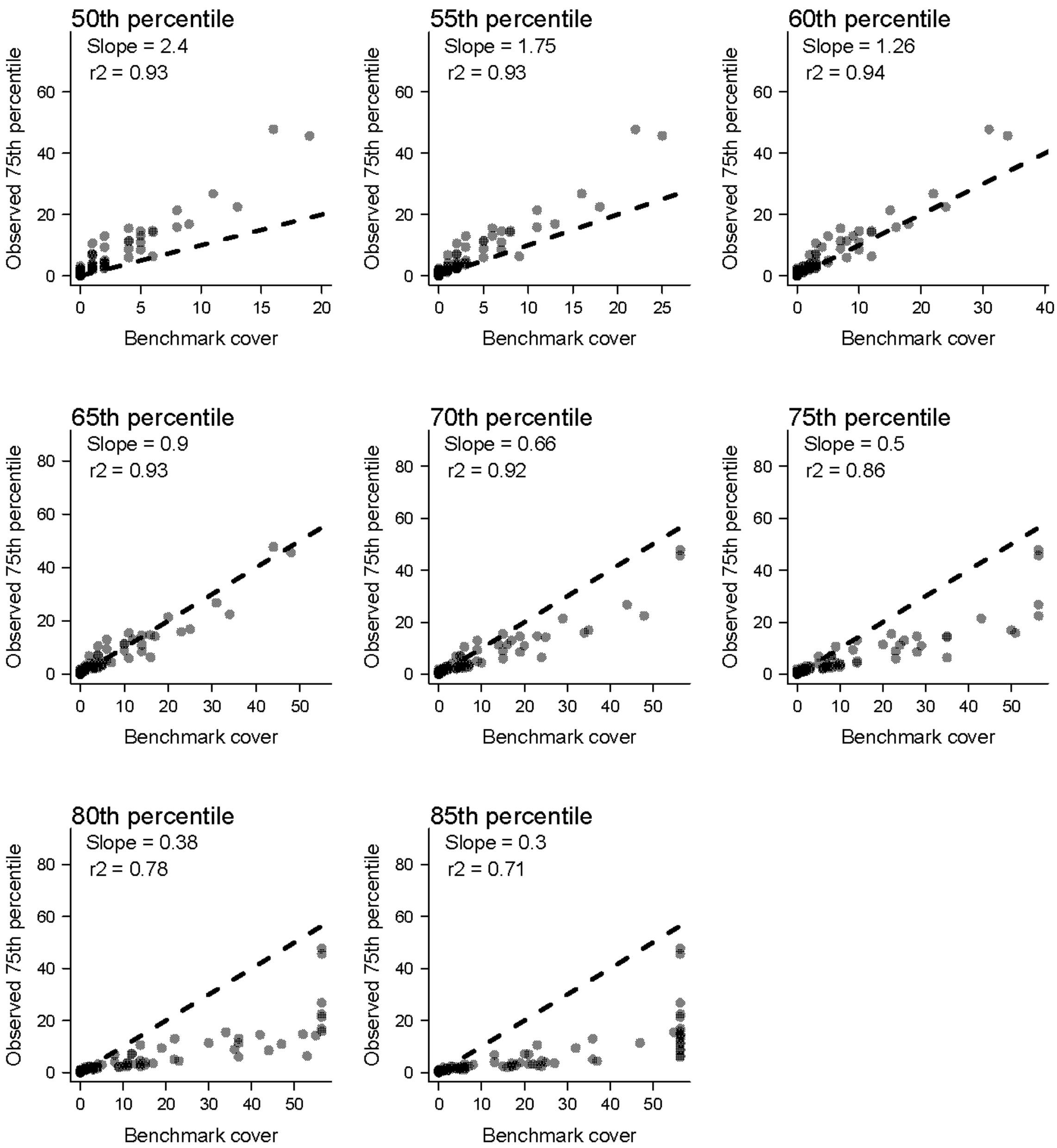

Figure 59 **Estimated versus observed other summed cover percentiles for RVCs with > 100 plots**

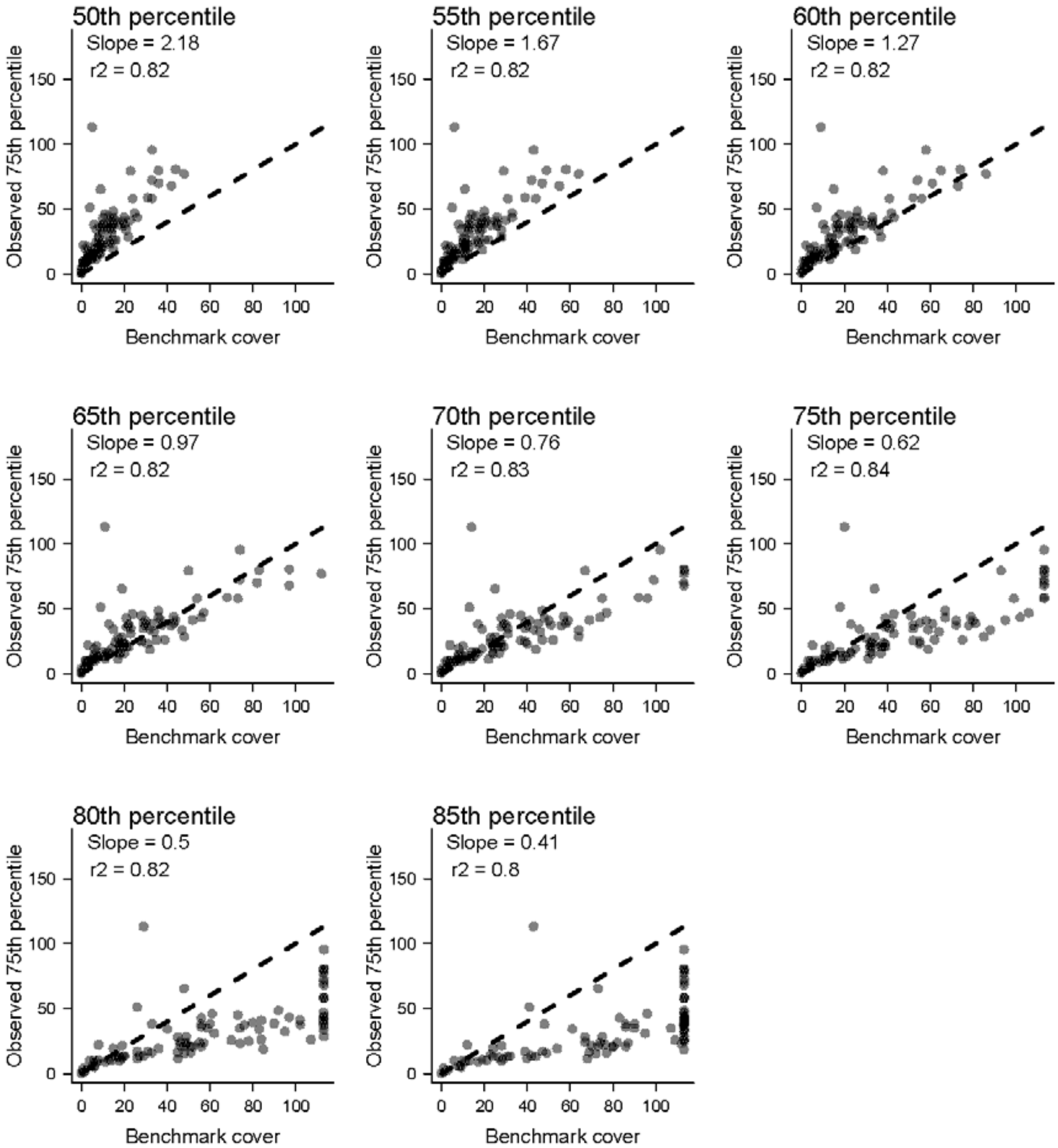

Figure 60 **Estimated versus observed shrub summed cover percentiles for RVCs with > 100 plots**

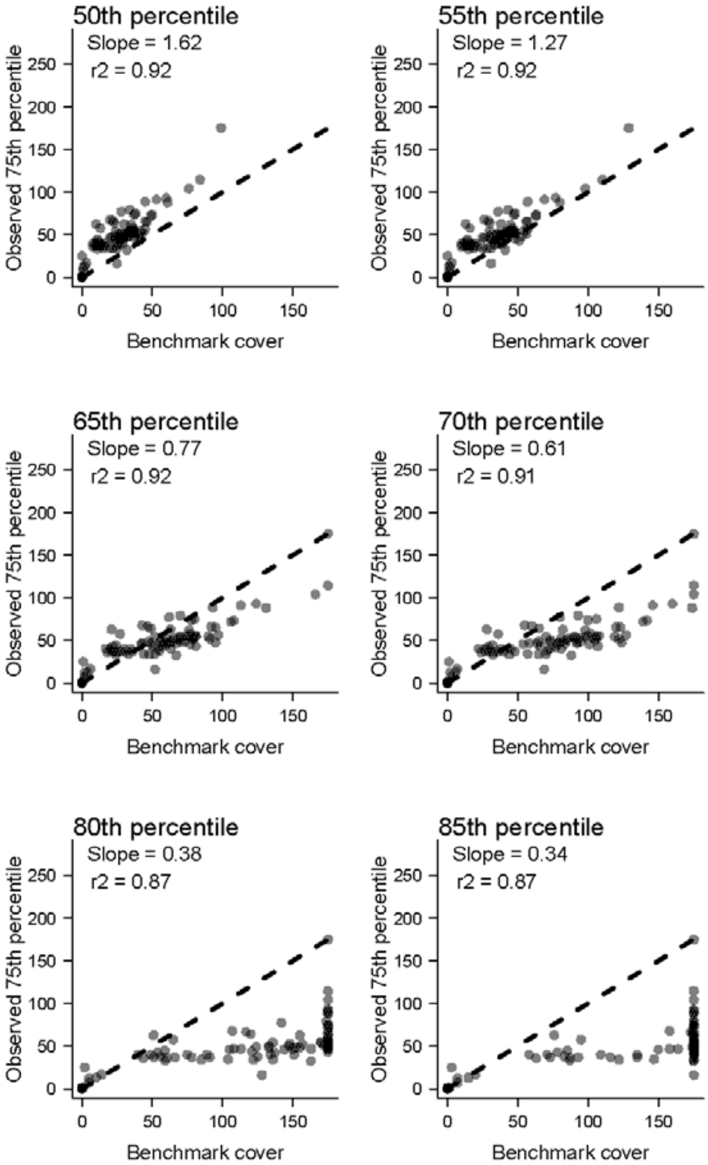

Figure 61 Estimated versus observed tree summed cover percentiles for RVCs with > 100 plots

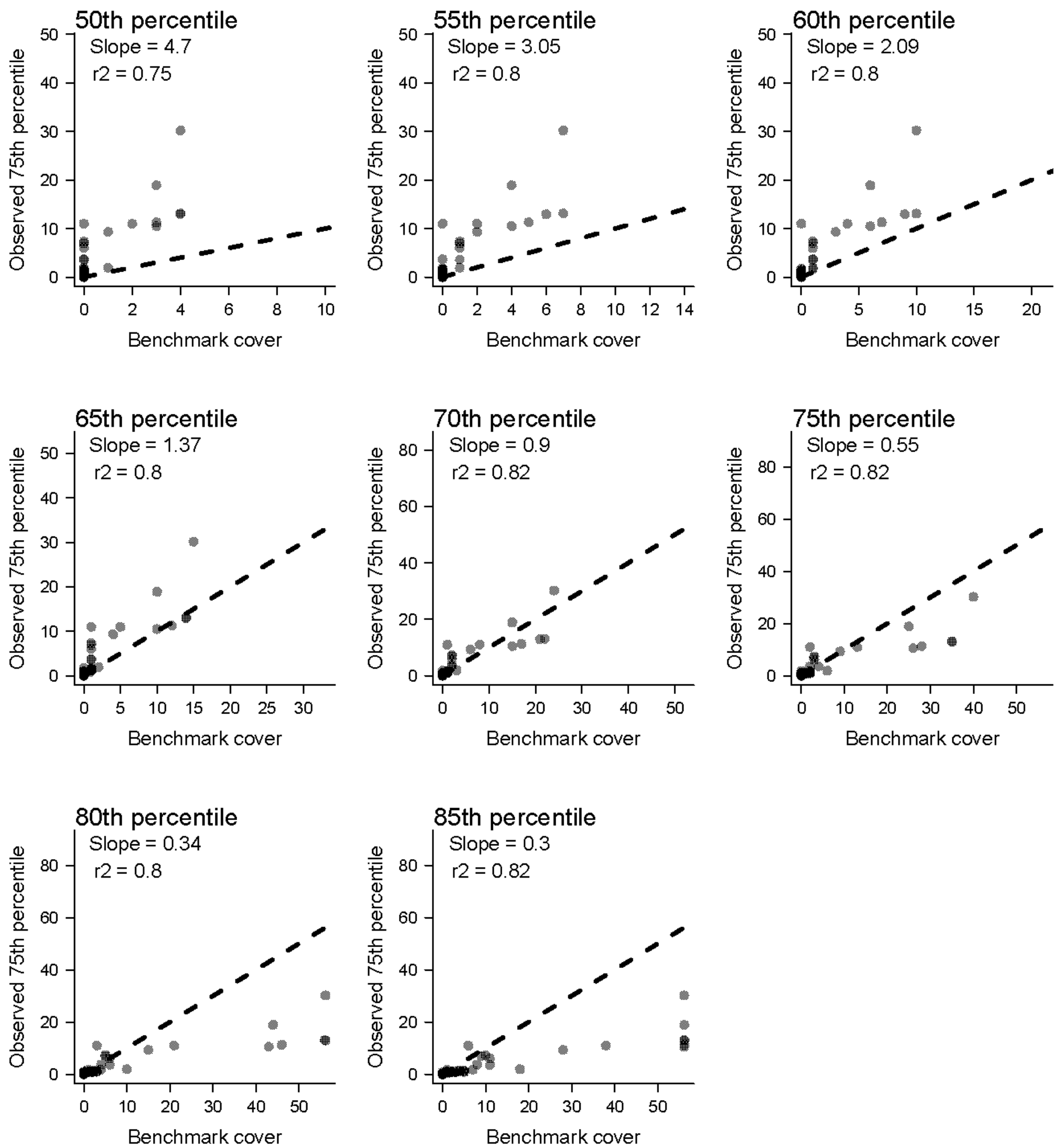

Figure 62 **Estimated versus observed fern summed cover percentiles for RVCs with > 200 plots**

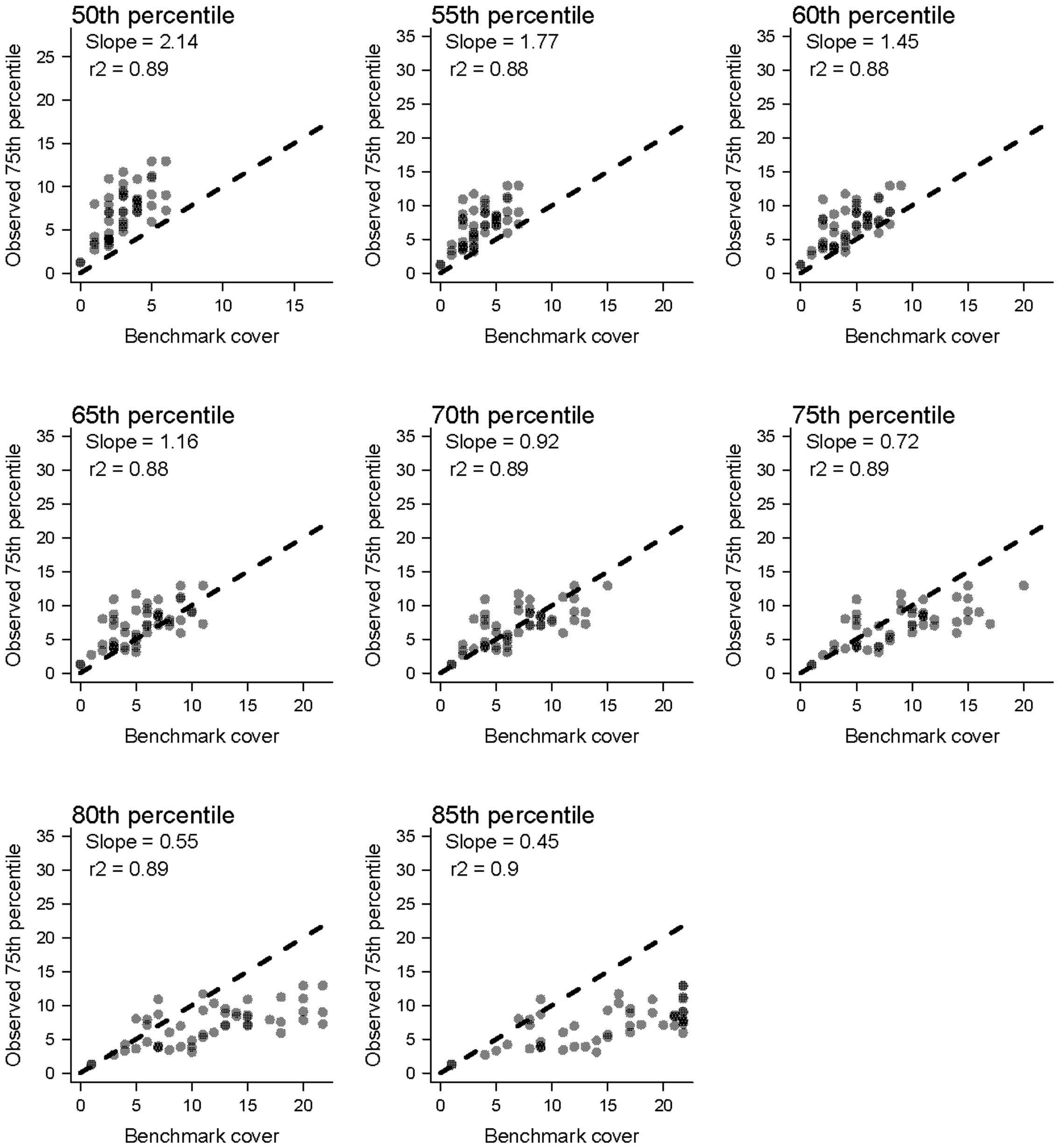

Figure 63 **Estimated versus observed forb summed cover percentiles for RVCs with > 200 plots**

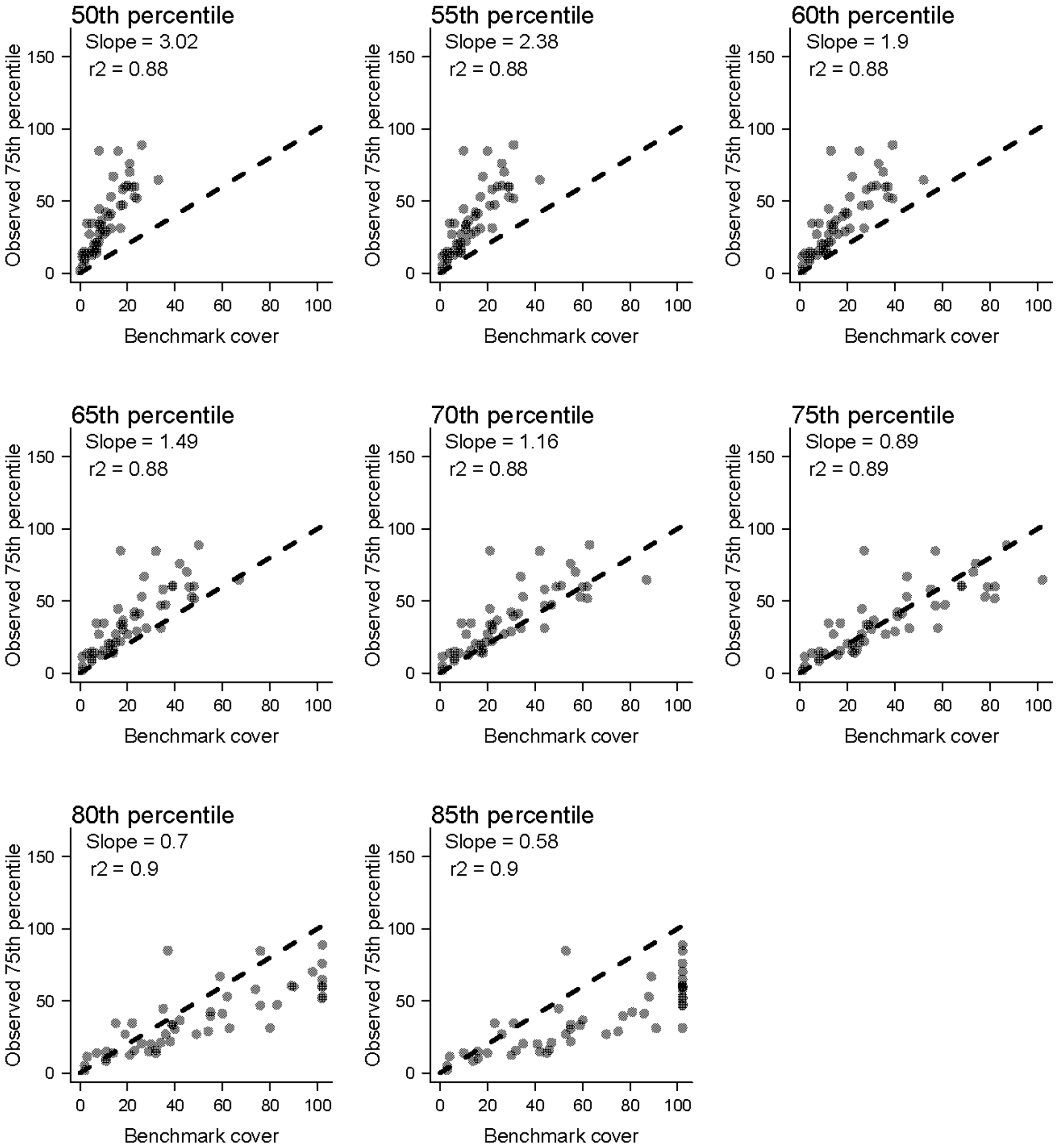

Figure 64 **Estimated versus observed grass summed cover percentiles for RVCs with > 200 plots**

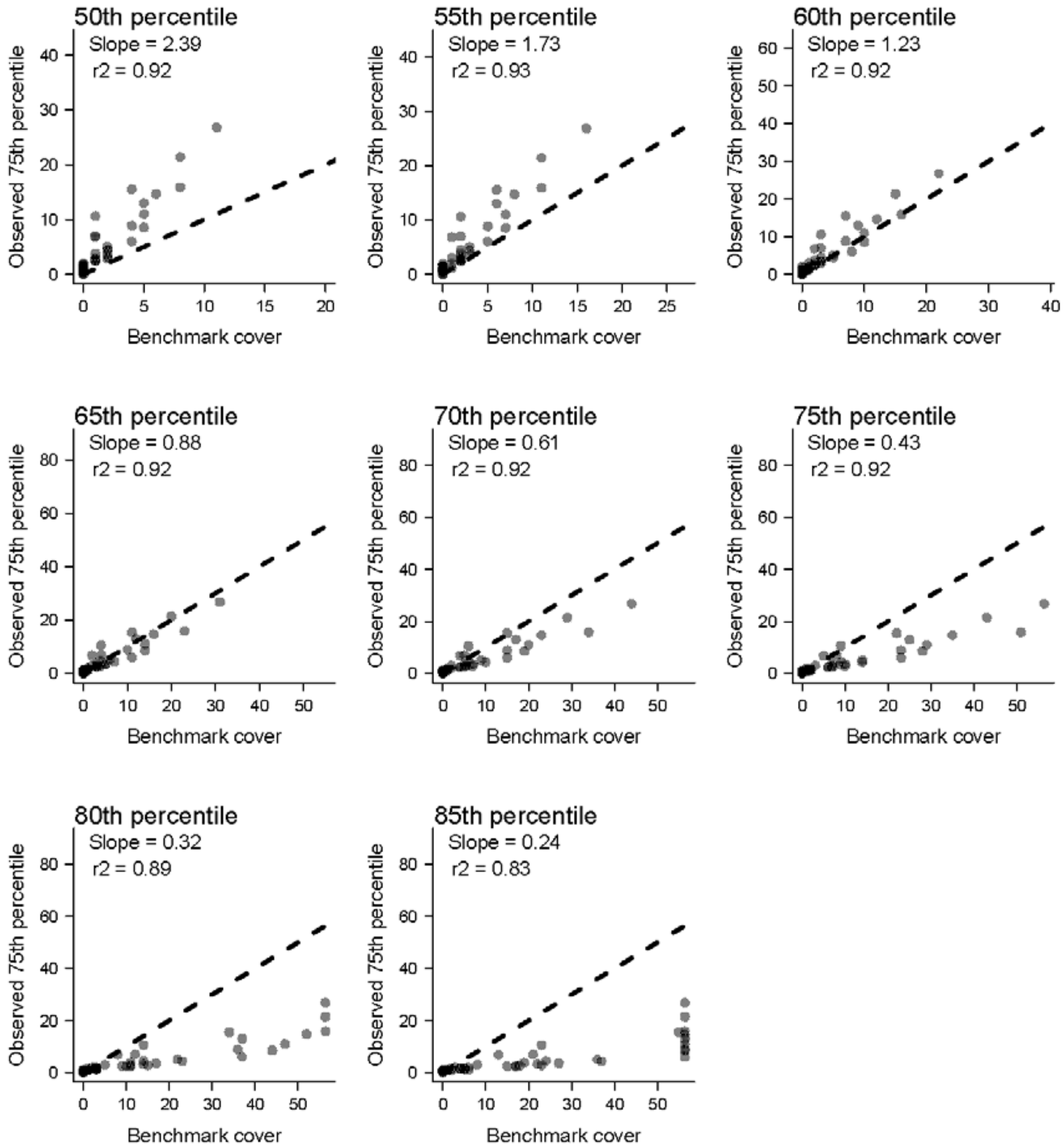

Figure 65 **Estimated versus observed other summed cover percentiles for RVCs with > 200 plots**

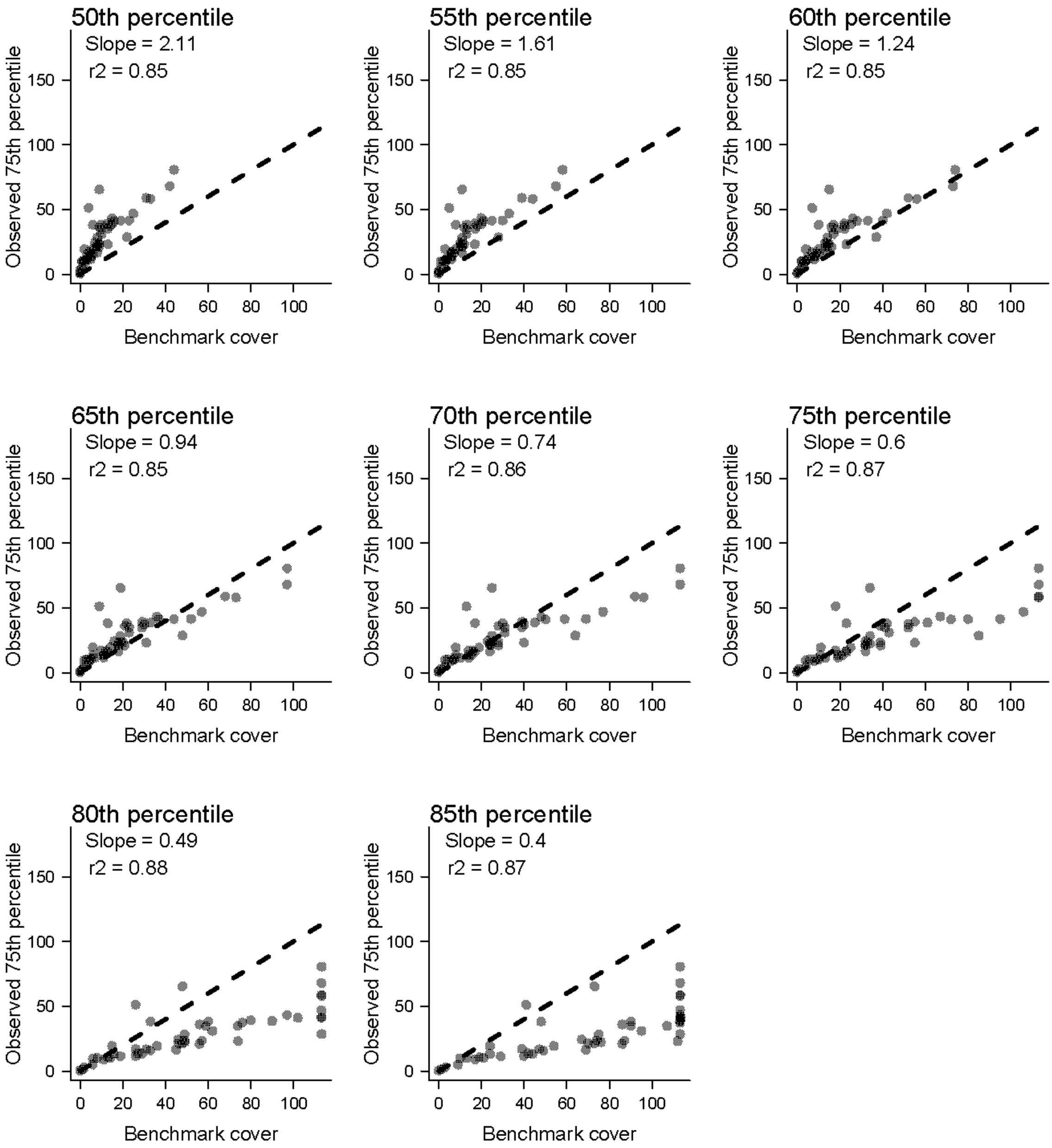

Figure 66 **Estimated versus observed shrub summed cover percentiles for RVCs with > 200 plots**

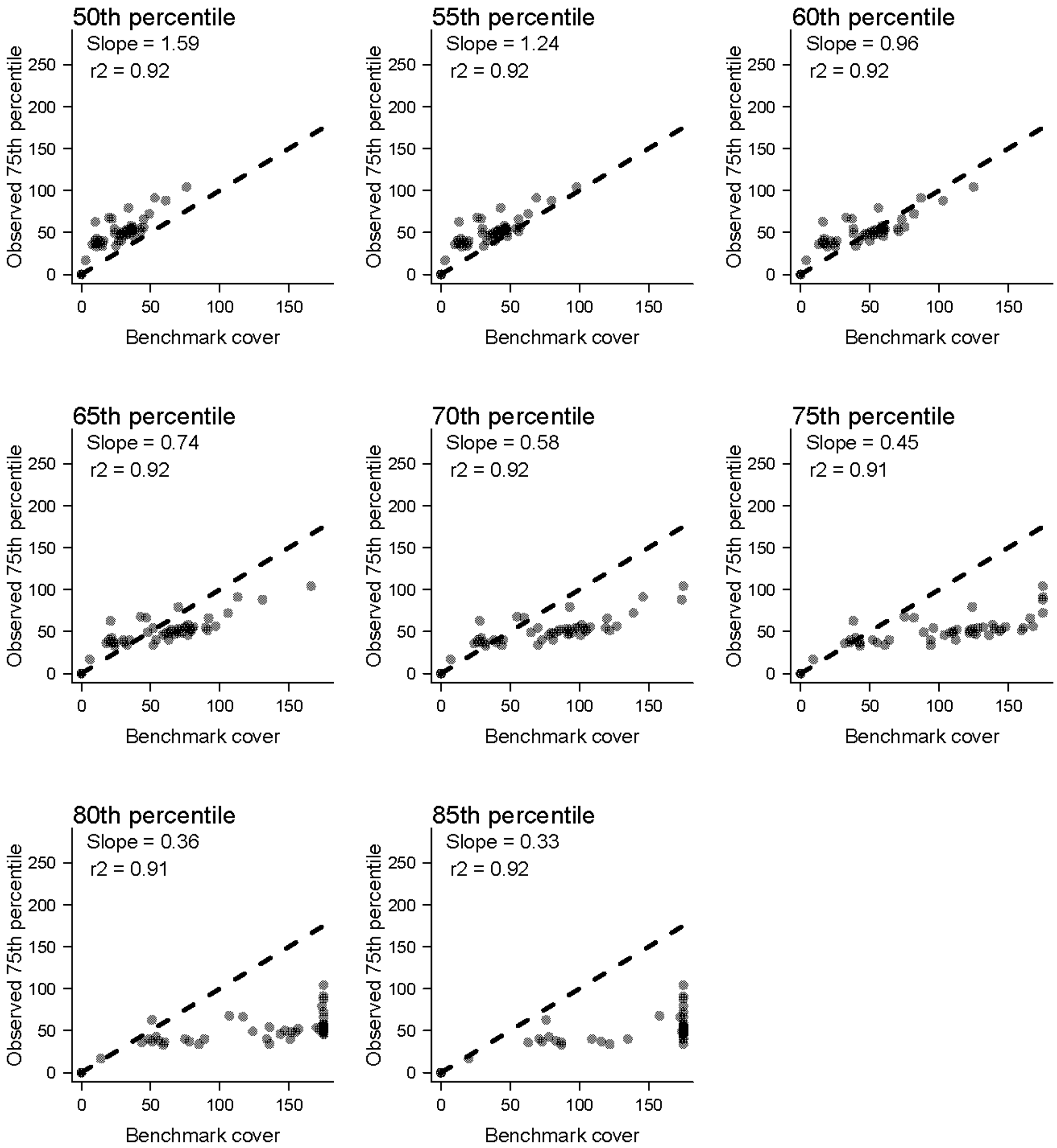

Figure 67 Estimated versus observed tree summed cover percentiles for RVCs with > 200 plots

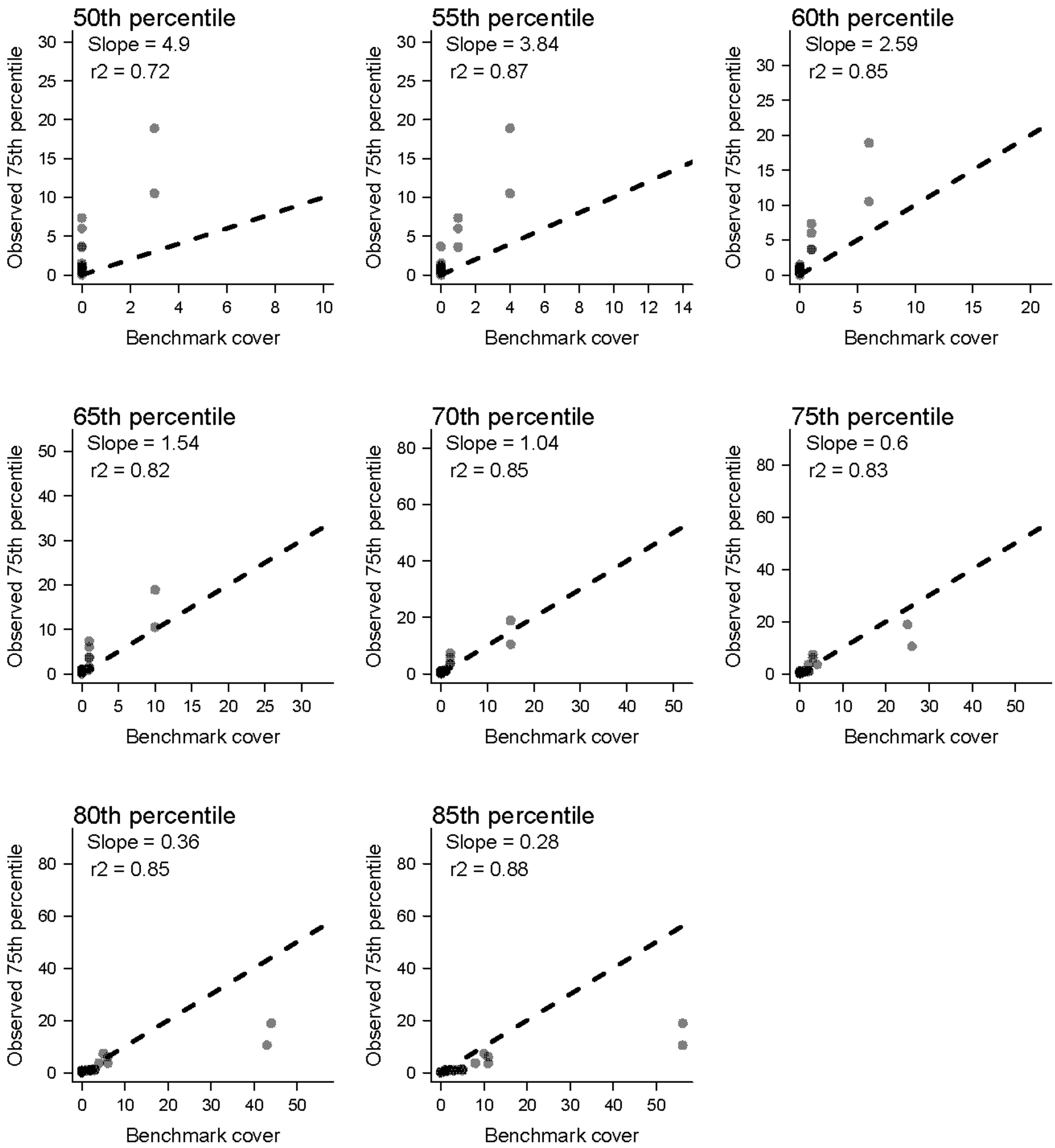

Figure 68 **Estimated versus observed fern summed cover percentiles for RVCs with > 300 plots**

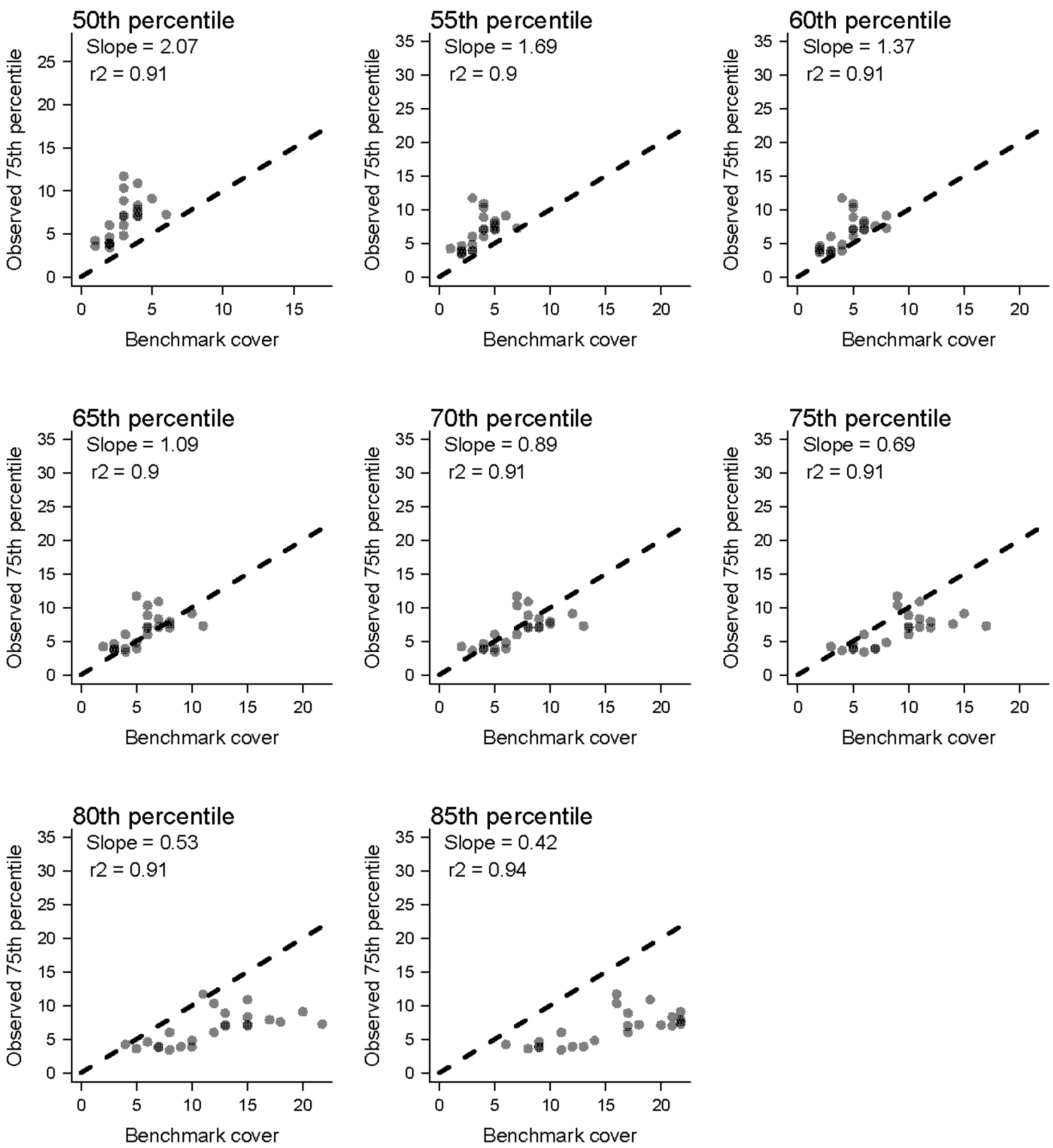

Figure 69 Estimated versus observed forb summed cover percentiles for RVCs with > 300 plots

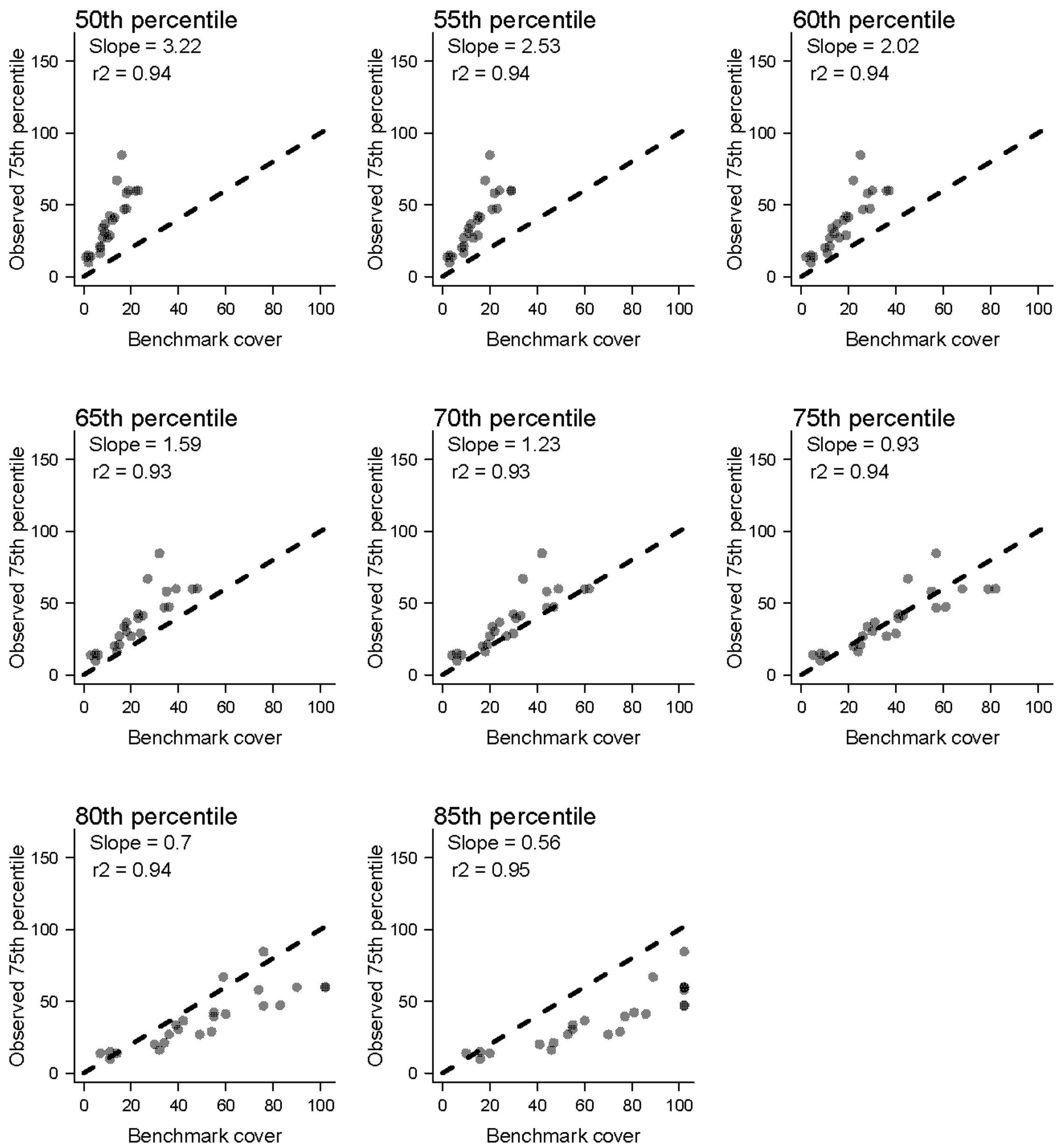

Figure 70 Estimated versus observed grass summed cover percentiles for RVCs with > 300 plots

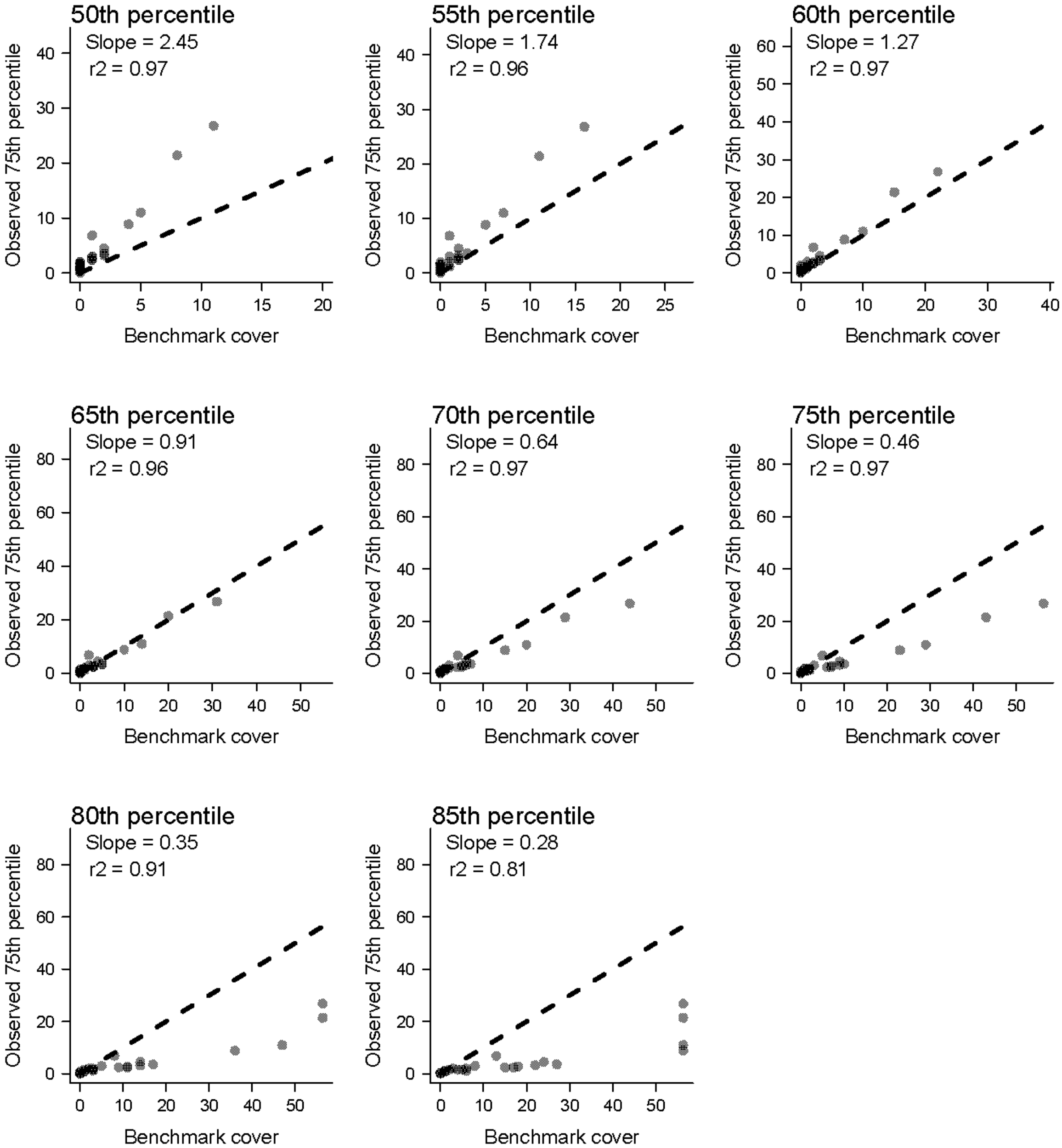

Figure 71 **Estimated versus observed other summed cover percentiles for RVCs with > 300 plots**

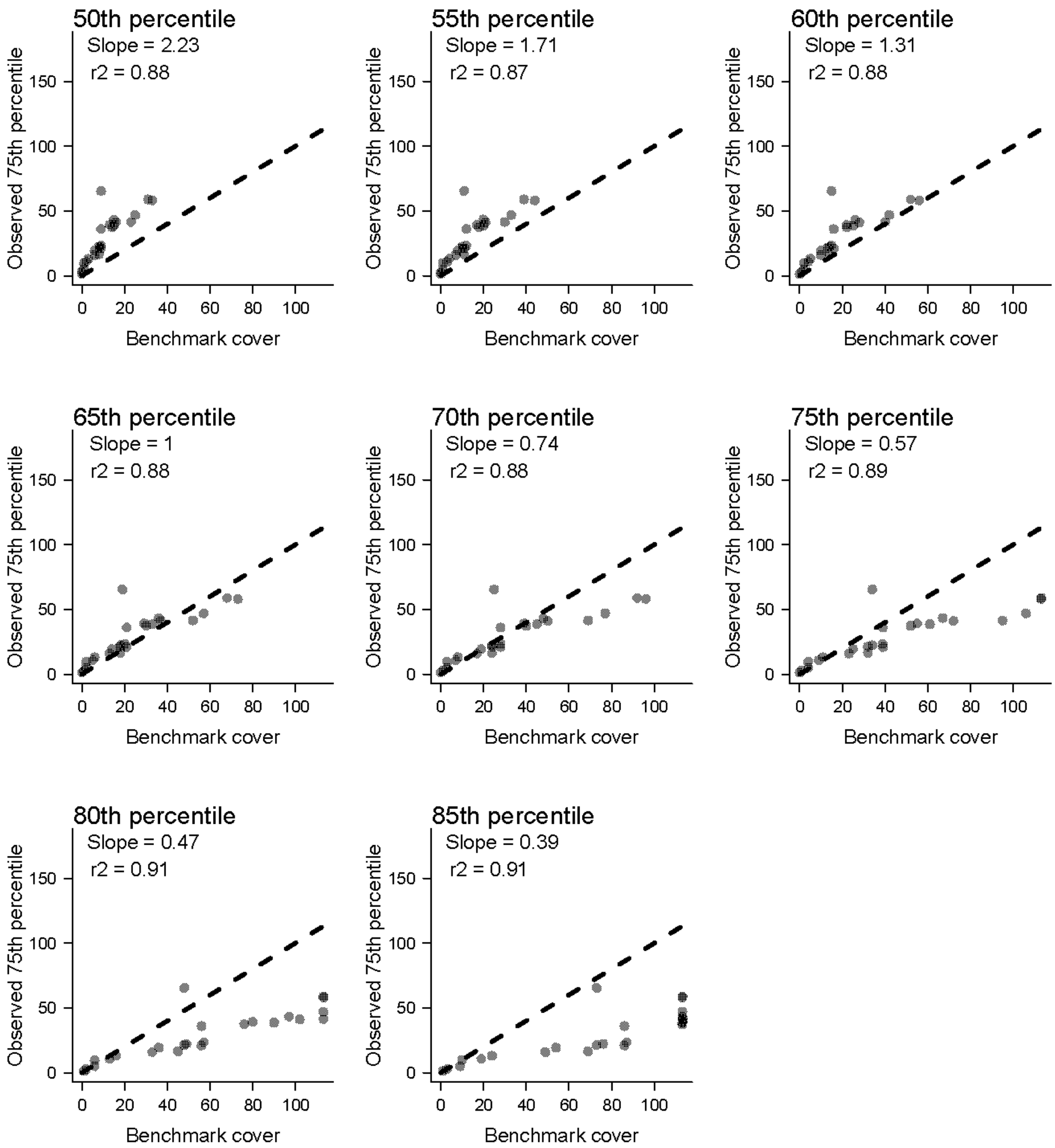

Figure 72 **Estimated versus observed shrub summed cover percentiles for RVCs with > 300 plots**

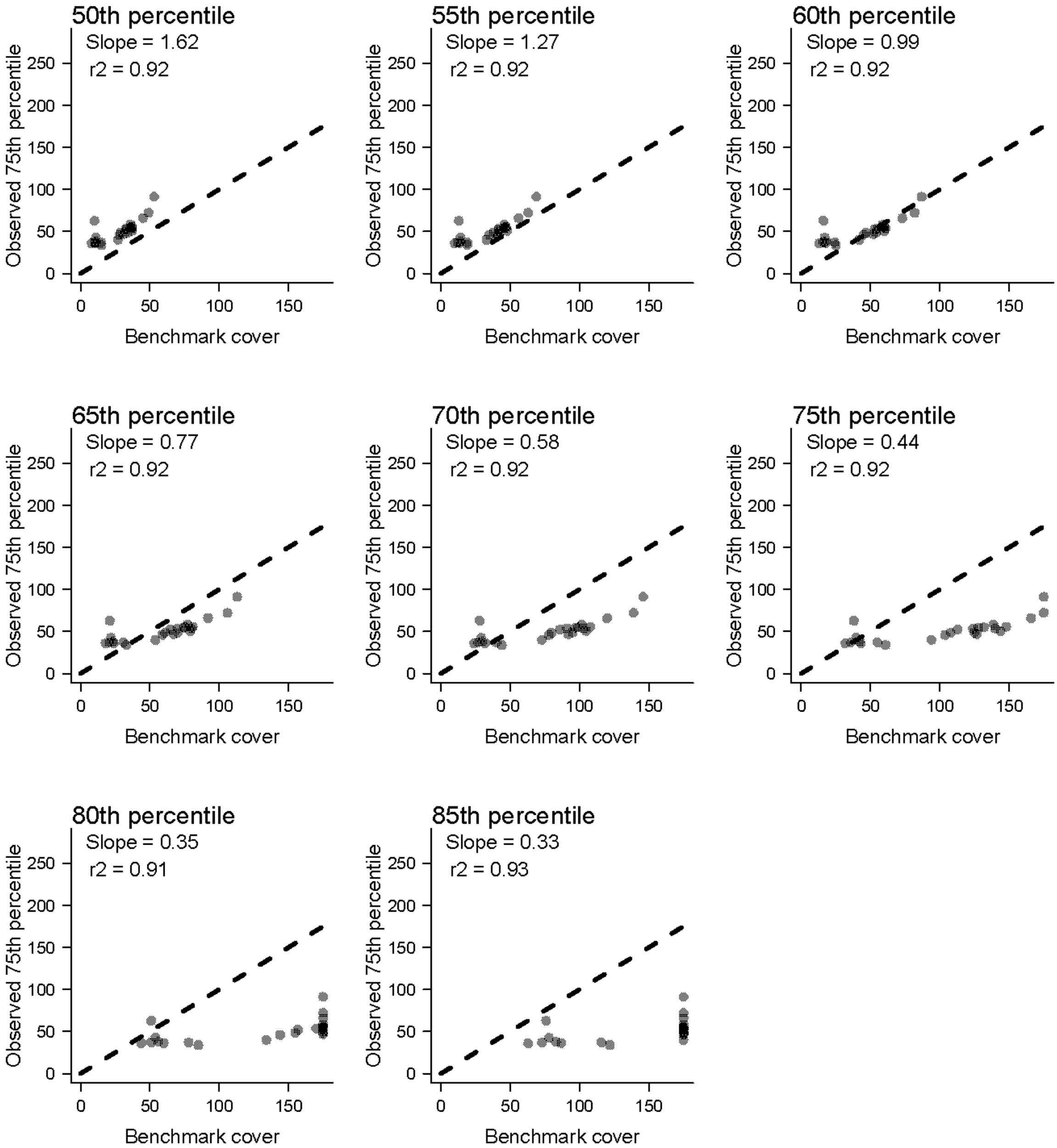

Figure 73 **Estimated versus observed tree summed cover percentiles for RVCs with > 300 plots**

Appendix 3 – Root mean squared deviation (RMSD)

Table 9 Root mean squared deviation (RMSD)

Between observed 75th cover percentiles and estimated cover percentiles for increasing number of plots per RVC. Red font indicates the selected growth form cover percentiles.

		RMSD				
	Estimated Percentile	**60th**	**65th**	**70th**	**75th**	**80th**
FERNS	>0 plots	6.82	6.24	6.02	7.16	9.51
	>20 plots	6.22	5.45	5.05	6.67	9.67
	>50 plots	4.53	3.89	3.91	6.23	10.06
	>100 plots	4.85	4.20	4.28	6.88	11.48
	>200 plots	4.49	3.59	3.20	5.72	12.27
	>300 plots	3.26	2.65	1.86	3.07	7.58
FORB	>0 plots	11.78	11.36	10.97	10.76	10.93
	>20 plots	5.04	4.42	3.99	4.03	5.33
	>50 plots	4.27	3.66	3.22	3.44	5.18
	>100 plots	3.70	3.00	2.63	3.07	5.16
	>200 plots	3.47	2.78	2.39	3.04	5.36
	>300 plots	2.92	2.25	2.14	3.08	5.57
GRASSES	>0 plots	29.05	26.31	24.14	24.01	26.97
	>20 plots	24.80	21.04	17.78	17.04	21.20
	>50 plots	24.85	20.59	16.27	14.71	19.27
	>100 plots	24.18	19.90	15.25	13.91	19.61
	>200 plots	25.03	20.67	16.09	15.04	21.79
	>300 plots	23.96	19.38	13.93	11.03	18.98
OTHERS	>0 plots	6.65	6.13	6.65	8.29	10.70
	>20 plots	5.28	5.22	6.80	9.74	12.90
	>50 plots	4.73	4.36	5.94	9.26	13.13
	>100 plots	3.08	2.43	5.14	9.32	13.79
	>200 plots	2.46	2.16	4.74	9.47	14.25
	>300 plots	2.14	1.48	4.56	9.18	12.96
SHRUBS	>0 plots	24.70	24.94	28.09	34.42	43.88
	>20 plots	21.02	19.33	21.05	26.79	37.74

				RMSD		
	>50 plots	20.58	18.49	20.22	26.52	38.11
	>100 plots	18.01	15.84	18.72	25.90	37.44
	>200 plots	14.46	12.65	16.04	22.90	32.91
	>300 plots	14.47	12.00	15.75	25.46	35.47
TREES	>0 plots	24.62	30.13	40.60	56.86	75.45
	>20 plots	18.48	24.87	37.91	57.58	78.65
	>50 plots	17.49	23.30	37.37	58.69	81.24
	>100 plots	15.01	22.59	38.19	60.57	84.34
	>200 plots	15.10	23.83	41.12	64.51	89.61
	>300 plots	14.89	22.57	41.09	65.81	93.36