Supplementary Information

Analysis of vegetation canopy spectral features and species discrimination in reclamation mining area using in situ hyperspectral data

Table S1 Chemical composition for each vegetation species (data sources: [11])

	Habitat	Restoration modes*	soluble sugar (mg/g)	free proline (μg/g)	malondialdehyde (nmol/g)	hydrogen peroxide (μmol/g)	chlorophyll (mg/g)
	shady	CK	-	174.83	-	-	2.16
	slope	OF	-	123.09	10.65	-	1.55
	habitat	CS	141.46	-	15.33	15.86	-
	sunny	CK	-	174.11	-	-	-
Elymus	slope	OF	-	-	-	-	-
nutans	habitat	CS	213.46	-		12.45	-
	flat	CK	186.81	421.31	12.12	-	-
	ground	OF	-	-	-	-	-
	habitat	CS	-	-	4.95	13.63	-
	Mean		**180.58**	**223.34**	**10.76**	**13.98**	**2.36**
	shady	CK	-	-	-	-	-
	slope	OF	-	328.26	6.33	-	1.32
	habitat	CS	194.02	216.93	5.27	6.78	1.82
	sunny	CK	-	185.79	7.97	-	1.79
Poa	slope	OF	-	-	-	-	2.25
crymophila	habitat	CS	-	209.84	-	11.32	-
	flat	CK	285.48	310.06	8.67	-	-
	ground	OF	-	259.29	4.14	15.34	-
	habitat	CS	-	232.97	-	-	-
	Mean		**239.75**	**249.02**	**6.476**	**11.15**	**1.795**
	shady	CK	-	181.34	-	-	-
	slope	OF	-	-	-	-	2.15
	habitat	CS	194.69	257.35	12.26	8.76	1.58
	sunny	CK	-	186.58	5.19	23.79	1.03
Festuca	slope	OF	-	-	-	-	1.63
sinens	habitat	CS	202.84	-	-	-	-
	flat	CK	213.59	288.45	9.98	-	-
	ground	OF	-	-	5.86	-	1.26
	habitat	CS	-	-	-	16.35	1.09
	Mean		**203.71**	**228.43**	**8.32**	**16.30**	**1.46**
Poa	shady	CK	-	-	-	-	-

pratensis	slope	OF	-	-	-	-	-
	habitat	CS	-	-	-	-	-
	sunny	CK	-	-	-	-	-
	slope	OF	-	-	-	-	-
	habitat	CS	-	-	-	-	-
	flat	CK	-	-	-	-	-
	ground	OF	-	-	-	-	-
	habitat	CS	-	-	-	-	-
natural vegetation	shady	CK	-	-	-	-	-
	slope	OF	-	-	-	-	-
	habitat	CS	-	-	-	-	-
	sunny	CK	-	-	-	-	-
	slope	OF	-	-	-	-	-
	habitat	CS	-	-	-	-	-
	flat	CK	-	-	-	-	-
	ground	OF	-	-	-	-	-
	habitat	CS	-	-	-	-	-

* Restoration modes including coal mine spoils planting (CK), organic fertilizer planting (OF) and cover soil planting (CS)

Table S2 Summary statistics of plant height for each vegetation species

	Min (cm)	Max (cm)	Mean (cm)	S.D. (cm)
Natural vegetation	1.00	25.00	8.19	6.51
Elymus nutans	5.00	50.00	18.95	12.07
Poa pratensis	5.00	70.00	28.80	16.09
Poa crymophila	10.00	70.00	39.78	19.01
Festuca sinensis	20.00	70.00	34.55	14.53

* S.D. stands for standard deviation

Table S3. Vegetation index and calculation formula.

Type	Vegetation Index	Abbr.	Equation	Reference
Narrowband Greenness	Red Edge Normalized Difference Vegetation	$RENDVI$	$RENDVI = (\rho_{750} - \rho_{705})/(\rho_{750} + \rho_{705})$	[75]
	Modified Red Edge Normalized Difference Vegetation	$MRENDV$	$MRENDVI = (\rho_{750} - \rho_{705})/(\rho_{750} + \rho_{705} - 2\rho_{455})$	[75]
	Modified Red Edge Simple Ration Index	$MRESRI$	$MRESRI = (\rho_{750} - \rho_{455})/(\rho_{750} + \rho_{455})$	[75]
	Vogelmann Index	VOG	$VOG = \rho_{740}/\rho_{720}$	[76]

Light Use Efficiency	Photochemical Reflectance Index	PRI	$PRI = (\rho_{531} - \rho_{570})/(\rho_{531} + \rho_{570})$	[77]
	Structure Insensitive Pigment Index	$SIPI$	$SIPI = (\rho_{800} - \rho_{455})/(\rho_{800} - \rho_{680})$	[78]
Dry or Senescent Carbon	Plant Senescence Reflectance Index	$PSRI$	$PSRI = (\rho_{680} - \rho_{500})/\rho_{750}$	[79]
Leaf Pigments	Carotenoid Reflectance Index 1	$CRI1$	$CRI1 = 1/\rho_{510} - 1/\rho_{550}$	[80]
	Carotenoid Reflectance Index 2	$CRI2$	$CRI1 = 1/\rho_{510} - 1/\rho_{700}$	
	Anthocyanin Reflectance Index 1	$ARI1$	$ARI1 = 1/\rho_{550} - 1/\rho_{700}$	
	Anthocyanin Reflectance Index 2	$ARI2$	$ARI1 = \rho_{800}$（$1/\rho_{550} - 1/\rho_{700}$）	
Canopy Water Content	Water Band Index	WBI	$WBI = \rho_{900}/\rho_{970}$	[81]
	Normalized Difference Water Index	$NDWI$	$NDWI = (\rho_{860} - \rho_{1240})/(\rho_{860} + \rho_{1240})$	[82]
	Moisture Stress Index	MSI	$MSI = \rho_{1599}/\rho_{819}$	[79]

Table S4. Spectral characteristic parameters and definitions.

Spectral transformation methods	**characteristic Parameters**	**Abbr.**	**Definition**	**Reference**
Original Spectra	Band reflectance	$Band_p$	Original band reflectance at p nm	[83]
	Blue valley reflectance	R_{bmin}	Minimum original spectrum at 430- 480 nm	
	Location of blue valley	λ_{bmin}	R_b corresponding wavelength	
	Green peak reflectance	R_{gmax}	Maximum original spectrum at 510- 560 nm	
	Location of green peak	λ_{gmax}	R_g corresponding wavelength	
	Red valley reflectance	R_{rmin}	Minimum original spectrum at 640- 680 nm	
	Location of red valley	λ_{rmin}	R_r corresponding wavelength	

Reciprocal logarithm transformed spectra	Blue peak reflectance	R_{bmax}	Maximum reciprocal logarithm at 430- 480 nm	[6]
	Location of blue peak	λ_{bmax}	R_{bmax} corresponding wavelength	
	Green valley reflectance	R_{gmin}	Minimum reciprocal logarithm at 510- 560 nm	
	Location of green valley	λ_{gmin}	R_{gmin} corresponding wavelength	
	Red peak reflectance	R_{rmax}	Maximum reciprocal logarithm at 640- 680 nm	
	Location of red peak	λ_{rmax}	R_{rmax} corresponding wavelength	
First order derivative transformed spectra	Blue edge amplitude	D_b	Maximum derivative value at 490-530 nm	[6]
	Blue edge position	λ_b	D_b corresponding wavelength	
	Yellow edge amplitude	D_y	Maximum derivative value at 560-640 nm	
	Yellow edge position	λ_y	D_y corresponding wavelength	
	Red edge amplitude	D_r	Maximum derivative value at 680-760 nm	
	Red edge position	λ_r	D_r corresponding wavelength	
Continuum removal transformed spectra	Absorption area	A_p	$A_p = (1 - R_p) * (\lambda_2 - \lambda_1)/2$	[84]
	Absorption slope	K_p	$K_p = (R_2 - R_1)/(\lambda_2 - \lambda_1)$	
	Absorption symmetry	S_p	$S_p = (\lambda_2 - \lambda_p)/(\lambda_2 - \lambda_1)$	

A_p, K_p and S_p refer to the absorption area, slope and symmetry of the absorption valley at p nm, λ_1, λ_2 and λ_p refer to the wavelengths at starting point, end point, and center of the absorption valley, and R_1, R_2, and R_p refer to the reflectance at starting point, end point, and center of the absorption valley.