remote sensing

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Supplementary Materials

A Review of Remote Sensing Challenges for Food Security with Respect to Salinity and Drought Threats

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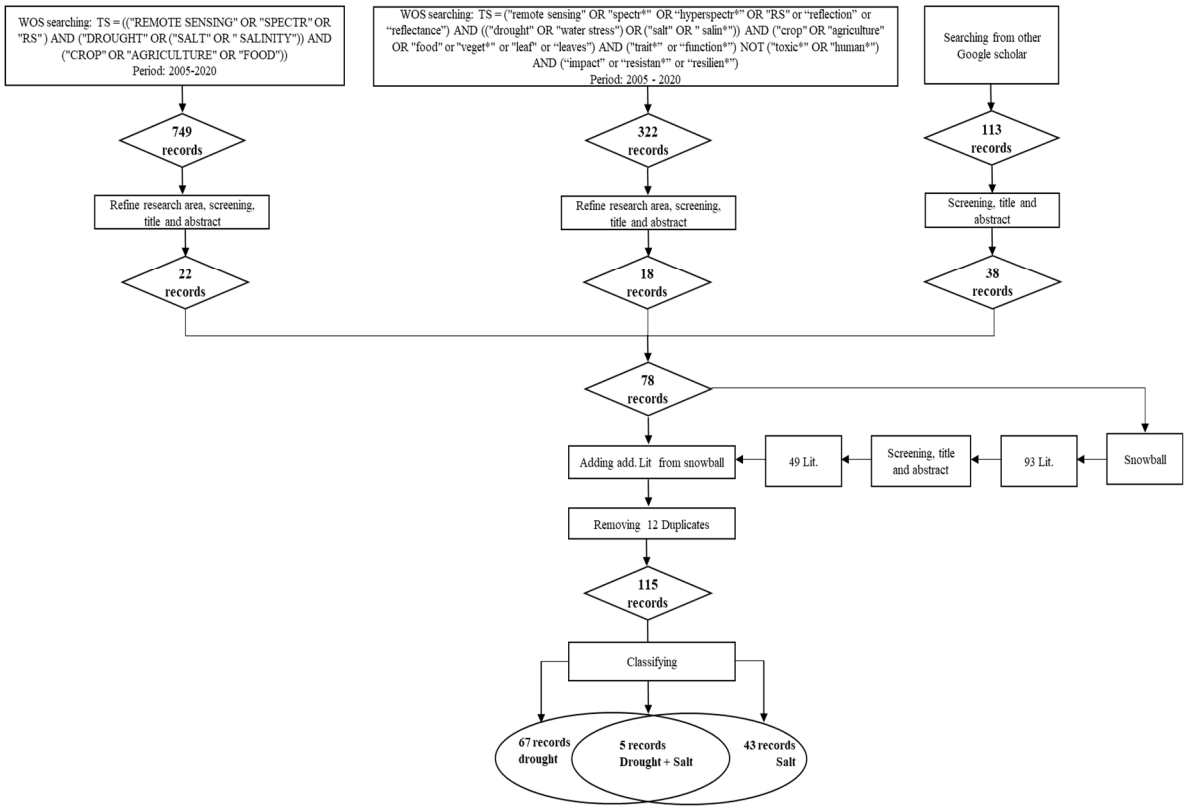

Figure S1. The flowchart of the systematic review.

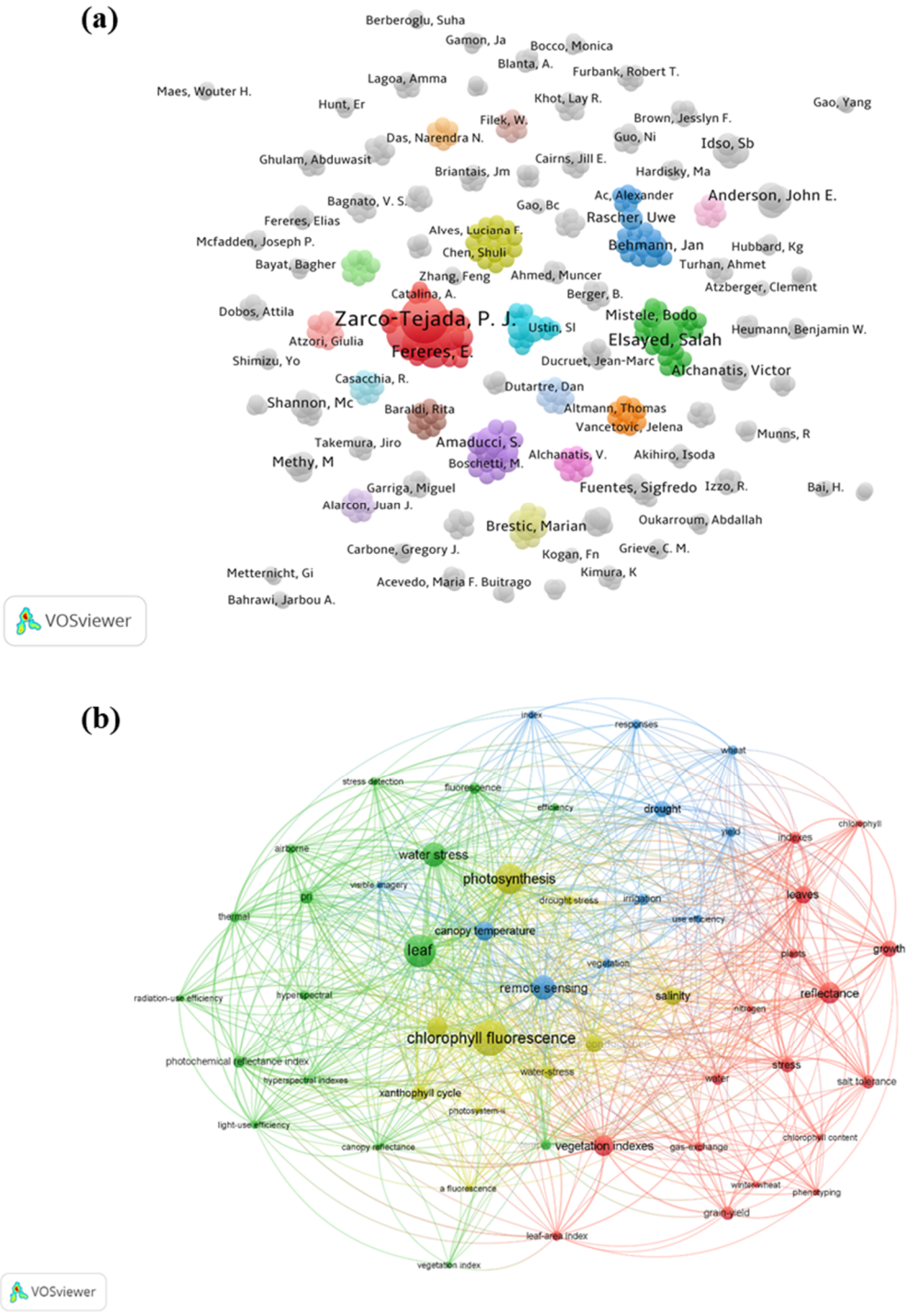

Figure S2. Maps of co-authors and co-occurrences from the results of the systematic review. A bubble and a tag constitute an element. The size of an element depends on the number of nodes, the strength of the line, and the number of citations. The color of an element represents the cluster to which it belongs, and different clusters are represented by different colors. In the co-author map, it shows the network of co-authorship links between 115 publications from the systematic review. The "bubbles" represent authors. The size of an author bubble represents the number of publications. Colors represent authors groups that are clustered by co-authorship links [1–3].

It was noticed that very few people are focusing on the topic of using remote sensing to monitor crop response to drought and salt stress. In addition, the connections among most authors were rather weak, and there was a very limited

number of studies focusing on monitoring crop traits responses to drought and salinity using remote sensing techniques, as the co-occurrence map showed that the connection of plant traits and spectra were rather weak. Therefore, we conclude that these topics need further investigation.

Table S1. 115 publications identified from the systematic review.

No.	Title	Reference
1	Detection of early plant stress responses in hyperspectral images	[4]
2	A crop-specific drought index for corn: I. Model development and validation	[5]
3	A field experiment on spectrometry of crop response to soil salinity	[6]
4	A PRI-based water stress index combining structural and chlorophyll effects: Assessment using diurnal narrow-band airborne imagery and the CWSI thermal index	[7]
5	Advanced phenotyping offers opportunities for improved breeding of forage and turf species	[8]
6	Advances in Remote Sensing of Agriculture: Context Description, Existing Operational Monitoring Systems and Major Information Needs	[9]
7	Aerial canopy temperature differences between fast- and slow-wilting soya bean genotypes	[10]
8	Agricultural drought monitoring: Progress, challenges, and prospects	[11]
9	Anatomy of a local-scale drought: Application of assimilated remote sensing products, crop model, and statistical methods to an agricultural drought study	[12]
10	Application of vegetation index and brightness temperature for drought detection	[13]
11	Application of visible and near-infrared spectrophotometry for detecting salinity effects on wheat leaves (*Triticum aestivum* L.)	[14]
12	Applying hyperspectral imaging to explore natural plant diversity towards improving salt stress tolerance	[15]
13	Assessing canopy PRI for water stress detection with diurnal airborne imagery	[16]
14	Assessing canopy PRI from airborne imagery to map water stress in maize	[17]
15	Assessment of Photochemical Reflectance Index as a Tool for Evaluation of Chlorophyll Fluorescence Parameters in Cotton and Peanut Cultivars Under Water Stress Condition	[18]
16	Assessment of the water status of mandarin and peach canopies using visible multispectral imagery	[19]
17	Associated changes in physiological parameters and spectral reflectance indices in olive (*Olea europaea* L.) leaves in response to different levels of water stress	[20]
18	Biophysical properties and biomass production of elephant grass under saline conditions	[21]
19	Broadband Spectral Reflectance Models of Turfgrass Species and Cultivars to Drought Stress	[22]
20	Can chlorophyll-a fluorescence parameters be used as bio-indicators to distinguish between drought and salinity stress in *Tilia cordata Mill*	[23]
21	Canopy temperature as a crop water stress indicator	[24]
22	Characterization of Crop Canopies and Water Stress Related Phenomena using Microwave Remote Sensing Methods: A Review	[25]
23	Chlorophyll fluorescence performance of sweet almond [Prunus dulcis (Miller) D. Webb] in response to salinity stress induced by NaCl	[26]
24	Chlorophyll, anthocyanin, and gas exchange changes assessed by spectroradiometry in *Fragaria chiloensis* under salt stress.	[27]
25	Comparative evaluation of the Vegetation Dryness Index (VDI), the Temperature Vegetation Dryness Index (TVDI) and the improved TVDI (iTVDI) for water stress detection in semi-arid regions of Iran	[28]

26	Computational water stress indices obtained from thermal image analysis of grapevine canopies	[29]
27	Crop yield prediction under soil salinity using satellite derived vegetation indices	[30]
28	Data fusion of spectral, thermal and canopy height parameters for improved yield prediction of drought stressed spring barley	[31]
29	Detecting salinity stress in tall fescue based on single leaf spectrum	[32]
30	Detecting water stress effects on fruit quality in orchards with time-series PRI airborne imagery	[33]
31	Detection of water stress in an olive orchard with thermal remote sensing imagery	[34]
32	Detection of water stress in orchard trees with a high-resolution spectrometer through chlorophyll fluorescence In-Filling of the O2-A band	[35]
33	Determining the Canopy Water Stress for Spring Wheat Using Canopy Hyperspectral Reflectance Data in Loess Plateau Semiarid Regions	[36]
34	Drought and Salinity Impacts on Bread Wheat in a Hydroponic Culture: A Physiological Comparison	[37]
35	Drought stress effects on photosystem I content and photosystem II thermotolerance analyzed using Chl a fluorescence kinetics in barley varieties differing in their drought tolerance	[38]
36	Early drought stress detection in cereals: Simplex Volume Maximization for hyperspectral image analysis	[39]
37	Effect of different concentrations of diluted seawater on yield and quality of lettuce	[40]
38	Effects of four types of sodium salt stress on plant growth and photosynthetic apparatus in sorghum leaves	[41]
39	Effects of saline reclaimed waters and deficit irrigation on Citrus physiology assessed by UAV remote sensing	[42]
40	Effects of salinity on physiological responses and the photochemical reflectance index in two co-occurring coastal shrubs	[43]
41	Estimating crop water stress with ETM+ NIR and SWIR data	[44]
42	Estimating growth and photosynthetic properties of wheat grown in simulated saline field conditions using hyperspectral reflectance sensing and multivariate analysis	[45]
43	Estimating Yields of Salt- and Water-Stressed Forages with Remote Sensing in the Visible and Near Infrared	[46]
44	Estimation of Canopy Water Content by Means of Hyperspectral Indices Based on Drought Stress Gradient Experiments of Maize in the North Plain	[47]
45	Estimation of Water Stress in Grapevines Using Proximal and Remote Sensing Methods	[48]
46	Evaluation of agronomic traits and spectral reflectance in Pacific Northwest winter wheat under rain-fed and irrigated conditions	[49]
47	Evaluation of Hyperspectral Reflectance Parameters to Assess the Leaf Water Content in Soybean	[50]
48	Evaluation of wavelengths and spectral reflectance indices for high-throughput assessment of growth, water relations and ion contents of wheat irrigated with saline water	[51]
49	Fluorescence excitation spectra of drought resistant and sensitive genotypes of triticale and maize	[52]
50	Fluorescence Spectroscopy to Detect Water Stress in Orange Trees	[53]
51	Fluorescence, PRI and canopy temperature for water stress detection in cereal crops	[54]
52	Fluorescence, temperature and narrow-band indices acquired from a UAV platform for water stress detection using a micro-hyperspectral imager and a thermal camera	[55]
53	Fluorescence-based sensing of drought-induced stress in the vegetative phase of four contrasting wheat genotypes	[56]

54	Genes and salt tolerance: bringing them together	[57]
55	Ground-based canopy sensing for detecting effects of water stress in cotton	[58]
56	High-throughput field phenotyping in dry bean using small unmanned aerial vehicle based multispectral imagery	[59]
57	Hyperspectral Reflectance Response of Freshwater Macrophytes to Salinity in a Brackish Subtropical Marsh	[60]
58	Hyperspectral remote sensing of salinity stress on red (*Rhizophora mangle*) and white (*Laguncularia racemosa*) mangroves on Galapagos Islands	[61]
59	Hyperspectral remote sensing to assess the water status, biomass, and yield of maize cultivars under salinity and water stress	[62]
60	Identifying leaf traits that signal stress in TIR spectra	[63]
61	Image-Derived Traits Related to Mid-Season Growth Performance of Maize Under Nitrogen and Water Stress	[64]
62	Imaging chlorophyll fluorescence with an airborne narrow-band multispectral camera for vegetation stress detection	[65]
63	Integrating satellite optical and thermal infrared observations for improving daily ecosystem functioning estimations during a drought episode	[66]
64	Interpretation of salinity and irrigation effects on soybean canopy reflectance in visible and near-infrared spectrum domain	[67]
65	Landsat images and crop model for evaluating water stress of rainfed soybean	[68]
66	Leaf chlorophyll fluorescence, reflectance, and physiological response to freshwater and saltwater flooding in the evergreen shrub, *Myrica cerifera*	[69]
67	Leaf-rolling in maize crops: from leaf scoring to canopy-level measurements for phenotyping	[70]
68	Linking leaf chlorophyll fluorescence properties to physiological responses for detection of salt and drought stress in coastal plant species	[71]
69	Linking physiological responses, chlorophyll fluorescence and hyperspectral imagery to detect salinity stress using the physiological reflectance index in the coastal shrub, *Myrica cerifera*	[72]
70	Measurement of leaf relative water content by infrared reflectance	[73]
71	Melon crops (*Cucumis melo* L., cv. Tendral) grown in a mediterranean environment under saline-sodic conditions: Part I. Yield and quality	[74]
72	Meta-analysis assessing potential of steady-state chlorophyll fluorescence for remote sensing detection of plant water, temperature and nitrogen stress	[75]
73	Modeling PRI for water stress detection using radiative transfer models	[76]
74	Monitoring agricultural drought for arid and humid regions using multi-sensor remote sensing data	[77]
75	Monitoring stomatal conductance of *Jatropha curcas* seedlings under different levels of water shortage with infrared thermography	[78]
76	Monitoring water stress and fruit quality in an orange orchard under regulated deficit irrigation using narrow-band structural and physiological remote sensing indices	[79]
77	Monitoring yield and fruit quality parameters in open-canopy tree crops under water stress. Implications for ASTER	[80]
78	Natural selection and neutral evolutionary processes contribute to genetic divergence in leaf traits across a precipitation gradient in the tropical oak *Quercus oleoides*	[81]
79	NDWI—A normalized difference water index for remote sensing of vegetation liquid water from space	[82]
80	New phenotyping methods for screening wheat and barley for beneficial responses to water deficit	[83]
81	Normalizing the stress-degree-day parameter for environmental variability	[84]

82	Perspectives for Remote Sensing with Unmanned Aerial Vehicles in Precision Agriculture	[85]
83	Phenotyping for Abiotic Stress Tolerance in Maize	[86]
84	Photochemical reflectance index as a mean of monitoring early water stress	[87]
85	Photochemistry, remotely sensed physiological reflectance index and de-epoxidation state of the xanthophyll cycle in *Quercus coccifera* under intense drought	[88]
86	Photosynthetic gas exchange, chlorophyll fluorescence and some associated metabolic changes in cowpea (*Vigna unguiculata*) during water stress and recovery	[89]
87	Potential and constraints of different seawater and freshwater blends as growing media for three vegetable crops	[90]
88	Radiation use efficiency, chlorophyll fluorescence, and reflectance indices associated with ontogenic changes in water limited Chenopodium quinoa leaves	[91]
89	Recovery responses of photosynthesis, transpiration, and stomatal conductance in kidney bean following drought stress	[92]
90	Relationships between net photosynthesis and steady-state chlorophyll fluorescence retrieved from airborne hyperspectral imagery	[93]
91	Relationships between stomatal behavior, spectral traits and water use and productivity of green peas (*Pisum sativum* L.) in dry seasons	[94]
92	Remote sensing of soil salinity: potentials and constraints	[95]
93	Risk identification of agricultural drought for sustainable Agroecosystems	[96]
94	Salinity tolerance and the decoupling of resource axis plant traits	[97]
95	Seasonal and drought-related changes in leaf area profiles depend on height and light environment in an Amazon forest	[98]
96	Seasonal patterns of reflectance indices, carotenoid pigments and photosynthesis of evergreen chaparral species	[99]
97	Simple reflectance indices track heat and water stress-induced changes in steady-state chlorophyll fluorescence at the canopy scale	[100]
98	Soil salinity mapping and hydrological drought indices assessment in arid environments based on remote sensing techniques	[101]
99	Spatial–spectral processing strategies for detection of salinity effects in cauliflower, aubergine and kohlrabi	[102]
100	Spectral assessments of wheat plants grown in pots and containers under saline conditions	[103]
101	Spectral indicators for salinity effects in crops: a comparison of a new green-indigo ratio with existing indices	[104]
102	Spectral indices for the detection of salinity effects in melon plants	[105]
103	Spectral Reflectance for Indirect Selection and Genome-Wide Association Analyses of Grain Yield and Drought Tolerance in North American Spring Wheat	[106]
104	Steady-State and Maximum Chlorophyll Fluorescence Responses to Water Stress in Grapevine Leaves: A New Remote Sensing System	[107]
105	The influence of diluted seawater and ripening stage on the content of antioxidants in fruits of different tomato genotypes	[108]
106	The influence of soil salinity, growth form, and leaf moisture on the spectral radiance o	[109]
107	The Photochemical Reflectance Index (PRI) as a water-stress index	[110]
108	The relationships between electrical conductivity of soil and reflectance of canopy, grain, and leaf of rice in northeastern Thailand	[111]
109	The use of infrared thermal imaging as a non-destructive screening tool for identifying drought-tolerant lentil genotypes	[112]
110	The Vegetation Drought Response Index (*VegDRI*): A New Drought Monitoring Approach for Vegetation	[113]

111	Thermal and Narrowband Multispectral Remote Sensing for Vegetation Monitoring From an Unmanned Aerial Vehicle	[114]
112	Use of thermal and visible imagery for estimating crop water status of irrigated grapevine	[115]
113	Using paired thermal and hyperspectral aerial imagery to quantify land surface temperature variability and assess crop stress within California	[116]
114	Utilization of a high-throughput shoot imaging system to examine the dynamic phenotypic responses of a C-4 cereal crop plant to nitrogen and water deficiency over time	[117]
115	Water stress detection in potato plants using leaf temperature, emissivity, and reflectance	[118]

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