USER GUIDE

Restoring Ecosystem Services Tool (REST) Program User Guide

SERDP Project RC-2117

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Acknowledgements

Data sources for species and functional traits are from available plant databases (please see full references). We are grateful for their permission.

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Dr. H. Keith Edwards provided coordination and technical assistance for student developers affiliated with this project via the CS 460 Software Engineering I and CS 461 Software Engineering II computer science courses at the University of Hawai‘i at Hilo.

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Acronyms

A_{max}	Maximal assimilation
C	Carbon
DBH	Diameter at breast height
GUI	Graphical user interface
LAR	Leaf area ratio
LDMC	Leaf dry matter content
LMA	Leaf mass per area
LWR	Leaf weight ratio
KMR	Keaukaha Military Reserve
N	Nitrogen
PCA	Principal Components Analysis
PCA #	Principal Component Axis #
P	Phosphorus
QE	Quantum efficiency
REST	Restoring Ecosystem Services Tool
UHH	University of Hawaii at Hilo
USDAFS	United States Department of Agriculture Forest Service

1.0 Introduction

The development of the Restoring Ecosystem Services Tool (REST) is a culmination of the SERDP project RC-2117, "Liko Nā Pilina: Developing Novel Ecosystems that Enhance Carbon Storage, Native Biodiversity, and Human Mobility in Lowland Hawaiian Forests". The project develops and evaluates a set of what we call "hybrid ecosystems," in which a mix of native and non-native species maintains valuable forest structure and ecosystem services. We have used community assembly rules and species-level information to design four experimental combinations of species. The Hawaiian name, *Liko Nā Pilina*, reflects the growing relationships that are developing in these new mixtures (Ostertag et al. 2015). We developed this approach because in our site invasion is so pervasive that often we cannot go back to all-native ecosystems on anything but the smallest scale, either economically or practically, and some non-native species may be playing important roles in the community in terms of providing ecosystem goods and services. The particular management goals of this experiment are to develop hybrid ecosystems that:

1. are resistant to invasion so that the hybrid ecosystems can maintain themselves with relatively little labor input;
2. are capable of sequestering substantial amounts of carbon;
3. sustain a broad range of native biological diversity; and
4. remain open enough at ground level to allow human movement through them.

While the *Liko Nā Pilina* project has specific restoration goals, the general approach of designing ecosystems with a set of species chosen to embody certain properties and functions is much broader. The REST tool described here is designed to help users with species choice in restoration. The tool does not give specific answers, but rather is meant to guide users who approach a restoration problem with specific restoration objectives and species in mind. The tool requires that the user identify a set of candidate species. Data on those species' functional traits are required; these data may be in the program if available from global databases (e.g., Jepson Flora Project 2006, Kattge et al. 2011, Paula & Pausas 2013, USDA NCRS 2016) or can be included by the user. The program provides a multivariate analysis of the species' data, providing the user with a handy visual of the relationships of the species to each other. This visual − a diagram of species in trait space − can then help the user chose species based on the user's needs. REST will not make any decisions, as those are left up to the user, but can be reset with different combinations of species to serve as an iterative tool that aids in decision making.

1.1 Background

At present, for any given parcel of land, developing a restoration strategy involves "best guesses." Under situations where managers would like to practice an active form of restoration by planting or encouraging specific species (Holl and Aide 2011), it is often the case that there is limited information about species ecology, genetics, physiology, and evolutionary biology (Jones 2013). Choosing plant species for restoration can be a difficult task because it is not always clear which species are the most appropriate to achieve a particular restoration goal. A multivariate approach that allows users to identify a range of species likely to help them meet restoration objectives is one potential solution. Appropriate species chosen based on their life history characteristics can then be combined in a simulated community to see how these species are related to each other in their characteristics. Because the metrics used are based on site-specific restoration objectives, this approach is generalizable, flexible, and transferable across ecosystems. This strategy for species selection is generalizable and flexible, allowing the user to choose species appropriate for desired functional outcomes, while acknowledging limiting factors such as economics (e.g., cost of seed/plants, labor, time), logistics (e.g., availability of species, project or budget timelines), predictability of climate, or disturbance regimes as well as the goals and expectations of stakeholders.

1.2 Importance of species selection in restoration

One major stumbling block in designing restoration plans is deciding on which species to use. The motivation for this approach to species choice comes from the desire to merge practical and ecological restoration techniques, as well as the recognition that species choice for restoration can be a difficult and value-laden process. There are practical concerns such as cost, availability of seeds, and ability to propagate that can partially dictate decisions. Yet in many cases, little is known about each species' life history and how each will interact with other species when planted together, particularly if the planting might represent new combinations that are not seen in the field. Situations where species are thrust together that do not share an evolutionary history provide relevant examples. These new combinations could arise because of non-native species invasion, range shifts of species due to climate change, or new species distributions due to land use activities. Although "novel ecosystems" (Hobbs et al. 2006) are becoming widespread, there is a very limiting understanding in the ecological literature about the long-term implications of new species interactions and their effects on ecosystem functioning.

1.3 The value of a functional traits restoration approach

The characteristics (or functional trait values) of a species reflect its life history − the establishment, growth, reproduction, and survival of a species. These functional trait values relate to a species' distribution in the wild, its competitive interactions with other species, and its use of biotic and abiotic resources (Reich et al. 2014). Furthermore, species also influence the environment via their functional traits (Reich et al. 2014); for example, the amount of nitrogen a species inputs to the soil via its leaf litterfall can be predicted from its leaf lifespan and its nutrient-use efficiency. Thus, functional traits reflect the compromises or tradeoffs a species faces at ecological and evolutionary time scales.

Because functional traits vary among species and environments in predictable ways, they can be linked to ecosystem properties – and thus be used in restoration to achieve specific objectives in ecosystem functioning (Funk et al. 2008). For example, the growth and recruitment of species with certain functional traits could be selected for by choosing species that facilitate plant and animal recruitment. If the objective is to build a community that will be less likely to burn, one could choose species with traits such as high leaf water content and low levels of volatile compounds.

While most studies attempting to link traits to ecosystem properties have been carried out in relatively simple systems, the field can be expanded to incorporate increasingly complex systems with higher diversity of species and life forms. A functional trait approach should be general enough to work across all ecosystems. The REST program allows the user to design new simulated communities to make some assessments about which combinations of species may be best for specific restoration goals. While the REST program has some data incorporated into it, it allows for users to enter their own species list and trait data. Thus, it is adaptable to any scenario a user wishes to portray.

This strategy for species selection is generalizable and flexible, allowing the user to choose the team members (species) and the desired functional outcomes, while acknowledging limiting factors such as economics (e.g., cost of seed/plants, labor, time), logistics (e.g., availability of species, project or budget timelines), predictability of climate or disturbance regimes, as well as the goals and expectations of stakeholders. The choice of species for restoration objectives is not limited to the scores from their traits alone, but could also incorporate other aspects, such as maintaining a diverse and resilient community which fosters the desired environmental outcomes. REST can be used iteratively; for example, it can be reset and run again after removing species to continually refine choices.

1.4 Importance of functional traits: what to consider

Another difficult question is the choice of traits. In general terms, there are some key traits that the literature suggests are central to understanding a species' life history. These are traits related to resource acquisition (foliar N), reproductive investment (seed mass), resource allocation patterns (specific leaf area, wood density/specific gravity, leaf life span) or dispersal (maximum plant height, seed mass) (Drenovsky and James 2010, Thomson et al. 2011, Douma et al. 2012, Sonnier et al. 2012, Fry et al. 2013). These six traits appear to be consistently applied in global analyses (Adler et al. 2014, van Bodegom et al. 2014, Kunstler et al. 2016). If you have no prior knowledge we would suggest that examining some or all of these six traits would be a good starting point.

In part, the restoration goals determine the traits that should be of interest to consider for a particular restoration project. For example, if the aim is to build an ecosystem that has low flammability so that it is tolerant of fires, traits such as bark thickness and leaf water content may be interest. When you chose a restoration goal in the REST program, it will populate with a list of suggested functional traits that might be linked to your restoration needs. In REST, we have compiled publicly available global databases that contain trait data for a variety of the world's species. However, there are many species with limited trait data and many species not in the program. For this reason, REST allows the user to import data on species and traits as a .csv file.

Another important consideration is whether traits are continuous variables or categorical variables. Examples of categorical variables might be dispersal type (wind, water, animal, gravity) or leaf venation. REST focuses on continuous variables because it uses a statistical technique, principal components analysis (PCA) that requires quantitative data. However, categorical variables could be added by the user by coding each category with a number. For example, if you wanted to include dispersal type, a file could be inputted with the dispersal type coded so that wind = 1, water = 2, animal = 3, and gravity = 4. In that case, the user would need to import data as a .csv file. Some important categorical variables include carbon pathway, growth habit, reproductive life history, shade tolerance, nitrogen-fixation capacity, and vegetative spread.

2.0 *Liko Nā Pilina* as an example of using functional traits

The Liko Nā Pilina project was used as an example to develop the underlying concepts and ideas that have gone into REST. It is a restoration experiment that is testing the long-term consequences of four different species mixtures in terms of increasing carbon storage, native biodiversity, and resisting invasive by undesired invasive species. Details on the functional trait approach used by the Liko Nā Pilina project can be found in Ostertag et al. (2015) and are briefly summarized here.

The Liko Nā Pilina experiment is in a lowland wet forest in Hilo, Hawai‘i. Research performed over the last decade in this ecosystem has shown that simply removing the highly invasive species (passive restoration) is not an effective restoration strategy. While removing the existing invasive species led to some increased native seedling regeneration, it had no effect on the growth of the native adult trees and led to a new invasive species composition (Cordell et al. 2009, Ostertag et al. 2009). The overall goal of the Liko Nā Pilina experiment was not to restore the site to an all native system, but to use functional trait theory to test how different mixtures of native and non-native but non-invasive species (i.e., hybrid ecosystems) differ in successional processes and ecosystem functioning. The trait-based method we used employs five steps:

Step 1. Articulate objectives and constraints

Because restoring this area to an all-native ecosystem is no longer economically feasible, we elected to create hybrid ecosystems. The long-term restoration objectives of the experiment are to increase carbon (C) storage, enhance native seedling regeneration, and provide invasion resistance.

Step 2. Select appropriate functional traits

We selected a set of traits related to successional facilitation and carbon storage (Table 1 from Ostertag et al. (2015). Two variables are categorical (stature and canopy architecture) and were given ordinal numbers as a code.

Step 3. Determine pool of species for trait sampling and restoration potential

We used 29 species as the species pool. From that list we aimed to use REST to condense to a smaller list. These species were chosen because they were known to persist in the lowland wet forest environment and were generally not considered invasive. Users must define their species pool based on contextually-unique objectives.

Table 1. List of functional traits measured in the candidate species for the *Liko Nā Pilina* experiment.

Functional Trait	**Biological Significance**	**Trait Range**	**Source of Data**
Leaf-to-petiole ratio	Light acquisition, self-shading	2.81 - 200.00	Measured
Leaf thickness (mm)	Resource acquisition, longevity, resource use	0.17 - 1.40	Measured
Leaf mass per area (g/m^2)	Photosynthesis, resource availability, longevity	8.24 - 469.22	Measured
Leaf N Percentage (%)	Concentration of RuBisCO, photosynthesis, fast to slow strategies	0.55 - 2.25	Measured
Leaf C Percentage (%)	Leaf construction, resource use	32.62 - 49.63	Measured
Leaf C:N	Leaf longevity, fast to slow strategies	14.82 - 79.78	Measured
Leaf P (%)	Leaf quality	trace - 0.30	Measured
Wood density/Specific gravity (g/cm^3)	Diameter growth rate, mortality rate, hydraulic capacity, carbon storage	0.16 - 1.51	Measured
Instantaneous water-use efficiency	Water use efficiency, resource use and acquisition	42.26 - 154.16	Calculated
Plant height at maturity (m)	Competitive vigor, plant fecundity, light acquisition	5-30	Bibliographic
Seed mass (g)	Dispersal, longevity, survival	<0.01 - 2.50	Bibliographic
Leaf area (cm^2)	Photosynthetic capacity, resource allocation	2.8 - >1000	Measured
Leaf water content (%)	Resource use and allocation, fast-slow strategies	2.59 - 85.9	Measured
Stature[a]	Dispersal, longevity, carbon storage	1-3	Observation
Canopy architecture[b]	Light interception, stability	1-3	Observation

[a]vertical position in the forest (1 = understory, 2 = mid-story, 3 = overstory)
[b]clustering of branches relative to the canopy (1 = bottom, 2 = middle, 3 = top)

Step 4. Collection and preparation of trait-data

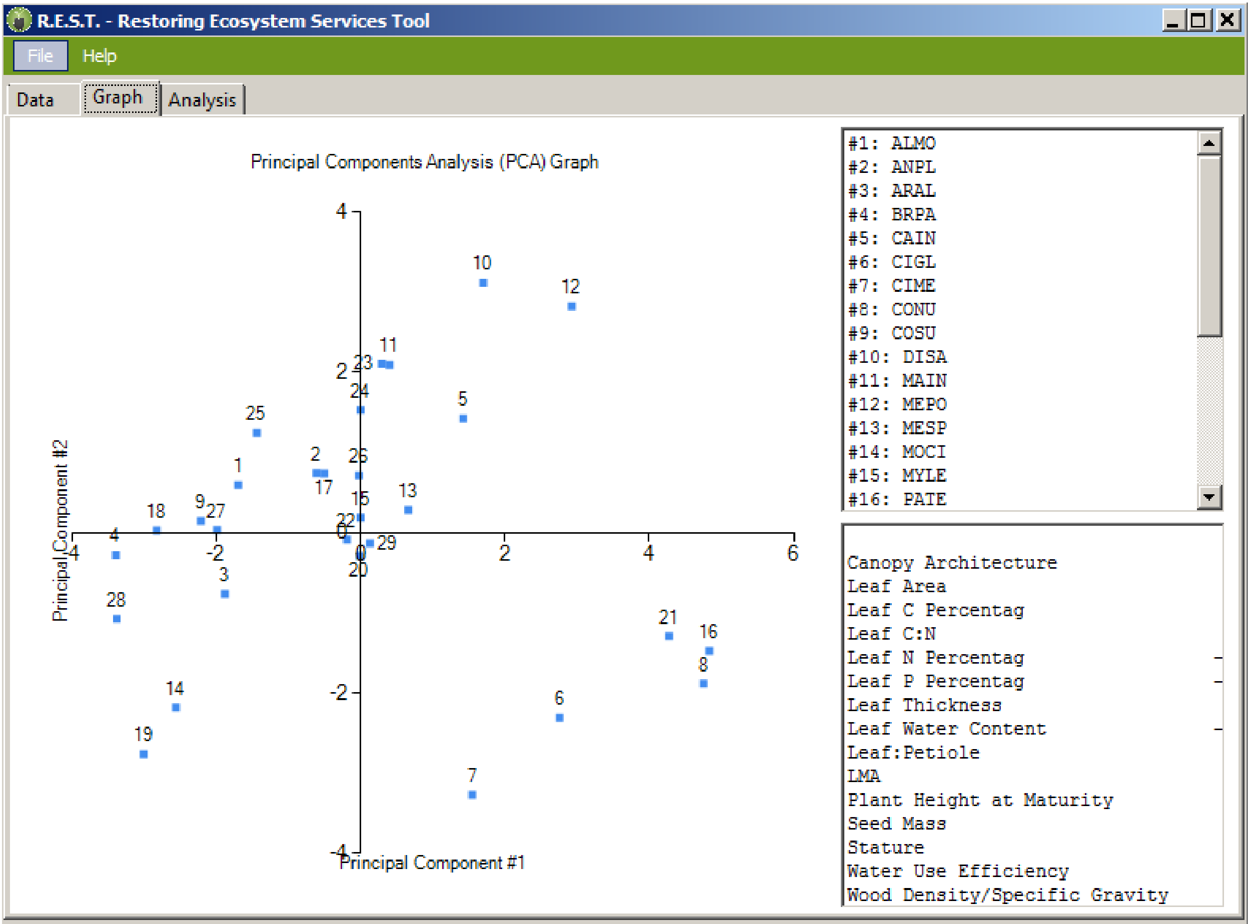
We sampled plant traits across the full range of conditions in which Hawaiian lowland wet forest is found regionally in order to account for both site and environmental heterogeneity. In total, we sampled traits at 25 sites throughout east Hawai‘i Island in addition to using existing data from the literature. By far the most time- and effort-consuming steps in making species choices via trait use involve creating the potential species pool and collecting trait data. However, some shortcuts can be taken for managers that do not have the resources to collect original data. REST contains some global trait databases while other data can be sought out through the literature. There are also a variety of resources that provide background on data collection methods. The *PrometheusWiki* (http://prometheuswiki.publish.csiro.au/tiki-custom_home.php) provides protocols in ecological and environmental plant physiology and is updated by the research community. Another useful reference is the work of Cornelissen and colleagues (2003, http://cef-cfr.ca/uploads/Membres/CornelissenProtocol.pdf), which provides standards for functional trait measurements.

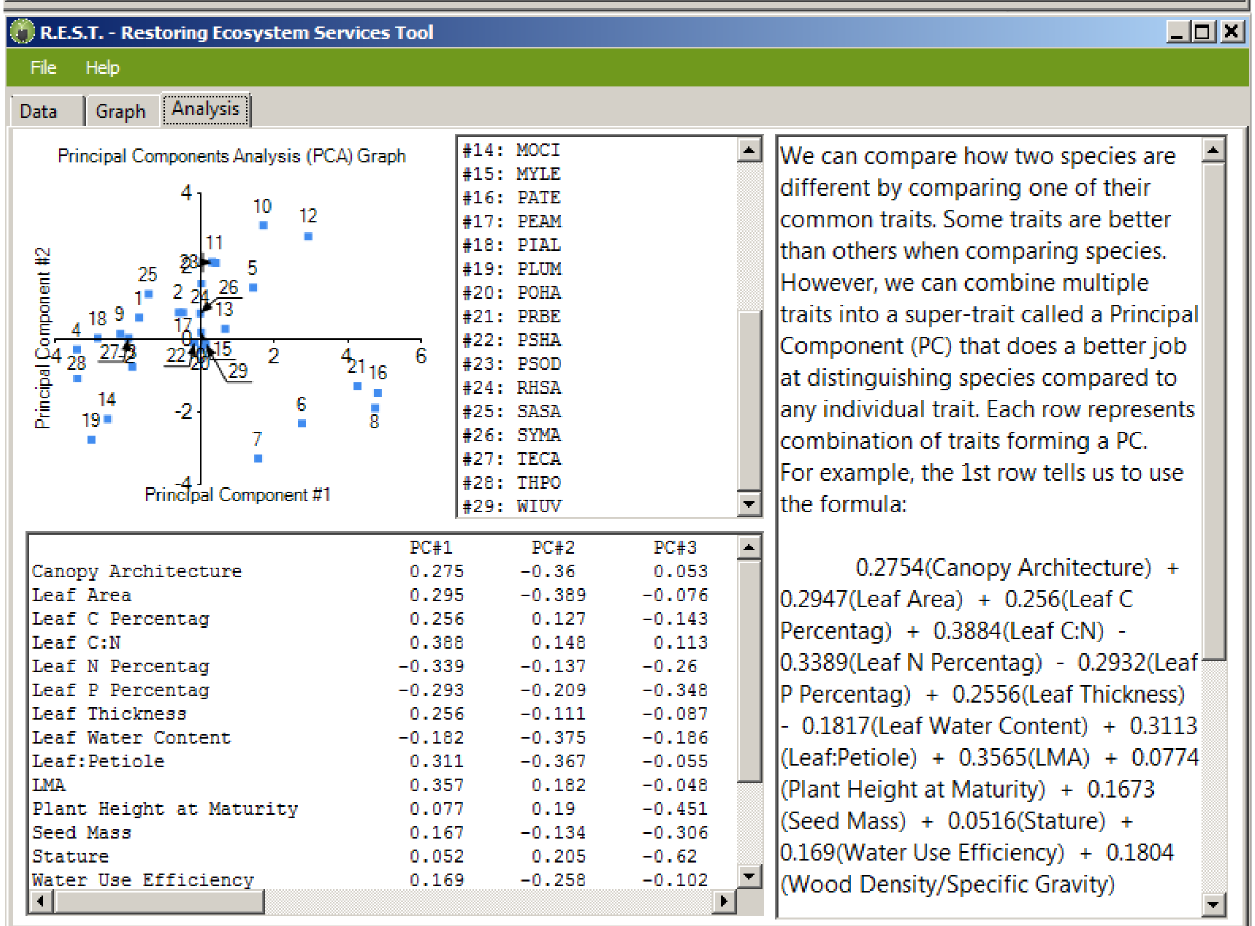
Step 5. Data analysis and final species choice

Data were uploaded into REST as a .csv file, with the main output is below. A total of 29 species and 15 traits were used in this example. The output below is a principal components analysis. Each species is a point in “trait space.” Points closer together are more similar. Points are evaluated for their closeness in two directions:

1. Horizontally along the x axis (Principal Component Axis 1; PCA 1)
2. Vertically along the y axis (PCA 2)

For example, species 7 and species 10 are very similar to each other along PCA 1 but not along PCA 2. In the subsequent output, you can determine that PCA 1 is the most correlated with the traits Leaf C:N Area (0.388) and LMA (0.357). Thus species 7 and species 10 are very similar in those traits. Positive values indicate that a trait increases its value as that axis increases value, while negative values indicate an inverse relationship. For example, as you move to the right along PCA 1, Leaf N Percentage values decrease (-0.339), so that species 7 and 10 would have lower leaf N concentrations than species 1 or 13. When examining along PCA 2, it is noted that PCA 2 is positively correlated with Wood Density yet negatively with Leaf Area. Thus, species 7 and species 10 are quite different in those two traits, a factor of their growth habits − species 7 is a tree fern and species 10 is a slow-growing canopy tree.


R.E.S.T. - Restoring Ecosystem Services Tool
File
Help
Data
Graph
Analysis
Principal Components Analysis (PCA) Graph
Principal Component #1
Principal Component #2
#1: ALMO
#2: ANPL
#3: ARAL
#4: BRPA
#5: CAIN
#6: CIGL
#7: CIME
#8: CONU
#9: COSU
#10: DISA
#11: MAIN
#12: MEPO
#13: MESP
#14: MOCI
#15: MYLE
#16: PATE
Canopy Architecture
Leaf Area
Leaf C Percentag
Leaf C:N
Leaf N Percentag
Leaf P Percentag
Leaf Thickness
Leaf Water Content
Leaf:Petiole
LMA
Plant Height at Maturity
Seed Mass
Stature
Water Use Efficiency
Wood Density/Specific Gravity


R.E.S.T. - Restoring Ecosystem Services Tool
File
Help
Data
Graph
Analysis
Principal Components Analysis (PCA) Graph
Principal Component #1
Principal Component #2
#14: MOCI
#15: MYLE
#16: PATE
#17: PEAM
#18: PIAL
#19: PLUM
#20: POHA
#21: PRBE
#22: PSHA
#23: PSOD
#24: RHSA
#25: SASA
#26: SYMA
#27: TECA
#28: THPO
#29: WIUV
PC#1 PC#2 PC#3
Canopy Architecture 0.275 -0.36 0.053
Leaf Area 0.295 -0.389 -0.076
Leaf C Percentag 0.256 0.127 -0.143
Leaf C:N 0.388 0.148 0.113
Leaf N Percentag -0.339 -0.137 -0.26
Leaf P Percentag -0.293 -0.209 -0.348
Leaf Thickness 0.256 -0.111 -0.087
Leaf Water Content -0.182 -0.375 -0.186
Leaf:Petiole 0.311 -0.367 -0.055
LMA 0.357 0.182 -0.048
Plant Height at Maturity 0.077 0.19 -0.451
Seed Mass 0.167 -0.134 -0.306
Stature 0.052 0.205 -0.62
Water Use Efficiency 0.169 -0.258 -0.102
We can compare how two species are different by comparing one of their common traits. Some traits are better than others when comparing species. However, we can combine multiple traits into a super-trait called a Principal Component (PC) that does a better job at distinguishing species compared to any individual trait. Each row represents combination of traits forming a PC.
For example, the 1st row tells us to use the formula:
0.2754(Canopy Architecture) + 0.2947(Leaf Area) + 0.256(Leaf C Percentag) + 0.3884(Leaf C:N) - 0.3389(Leaf N Percentag) - 0.2932(Leaf P Percentag) + 0.2556(Leaf Thickness) - 0.1817(Leaf Water Content) + 0.3113 (Leaf:Petiole) + 0.3565(LMA) + 0.0774 (Plant Height at Maturity) + 0.1673 (Seed Mass) + 0.0516(Stature) + 0.169(Water Use Efficiency) + 0.1804 (Wood Density/Specific Gravity)

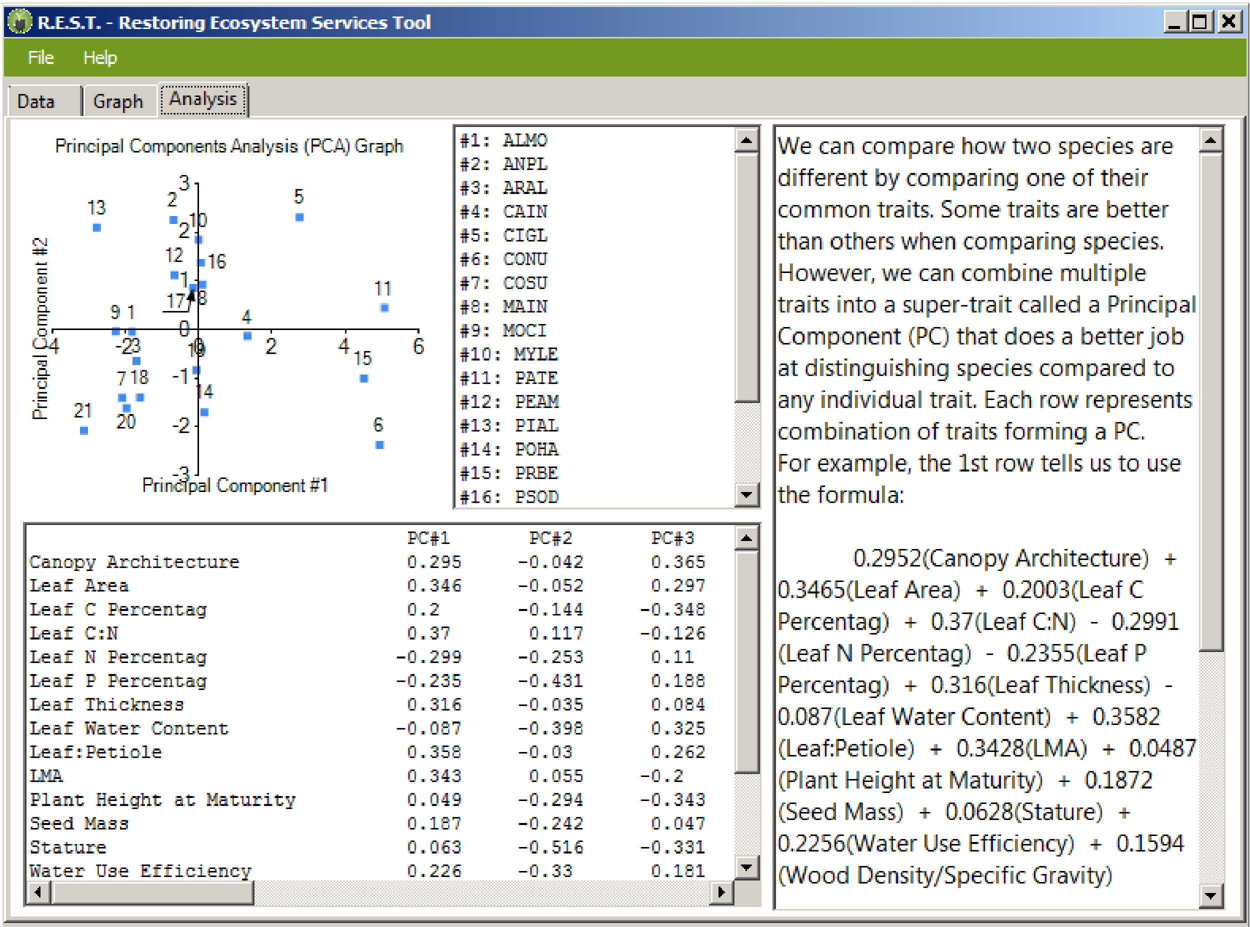
Another important output to consider is the eigenvalues and variation explained by examining the data along these two dimensions. An eigenvalue reflects the amount of variance in the data in a given axis direction (Keogh and Quinn 2002). For using REST, understanding the percent of variation explained is sufficient. The output below shows that the first axis PCA 1 explains about 36% of the variation in the data. Adding the second axis PCA 2 explains another 17%, for a total of about 53% of the variation explained. It is unlikely that principal components analysis will ever explain all of the variation in two axes, particularly if there are many traits. In addition, many of the traits examined may be correlated with each other. However, this information can guide us to see how confident we feel about the species characterizations. In this example, we can feel like the graph shows us a reasonable idea of how the species are related to each other.

E-Values	5.4559	2.5807	1.8764
%	0.3637	0.172	0.1251
% (Cum)	0.3637	0.5358	0.6609

Based on the graph we made some decisions to eliminate some species:

- Species 6 and species 7 are both tree ferns. As they are closer together on the PCA, we decided to include only one of them, with species 6 was more available from growers.
- Species 4 is similar to species 28. However, species 4 presents propagation challenges, guiding selection toward species 28.
- We used a similar logic with species 14 and species 19 − we eliminated species 19 because it does not regenerate on its own.
- Species 15 was similar to species 13. On site, species 13 would be placed at the lowest elevation of its range, potentially affecting survivorship potential. Thus, we eliminated species 13 in favor of species 15.
- Species 26 and species 29 were also similar. We eliminated species 29 as it is less common in the lowland wet forest environment than species 26.
- We also decided to eliminate the canopy trees already existing on site (species 10, 12, and 22).

REST can then be re-run without these species to check species relationships or to make further decisions. Note that the graph looks different than the first run. **REST is best used as an iterative tool to try different combinations of species**. Limiting factors that practitioners should consider include economics (e.g., cost of seed/plants, labor or time), logistics (e.g., availability of species, project or budget timelines), resilience to climatic change or disturbance regimes, as well as the goals and expectations of stakeholders.



The process allows for an unbiased way to let the data dictate a first step, and then the practical concerns of practitioners can be layered onto the final species choices.

3.0 Technical Overview

REST was constructed using Microsoft's Visual Studio 2015 Windows Forms platform. The main program is comprised of three parts: Graphical User Interface (GUI), Database, and Analysis. The GUI was created exclusively with tools found in the Windows Forms resources. The database itself is hosted on a private website implemented using PHPmyAdmin, updated periodically as new data becomes available. The analysis portion includes all algorithms and functions hidden from the user. Principal component analysis (PCA) output graphs are generated using the Accord.Net open source framework. At this time, REST is optimized for Windows-based operating systems only (other platforms may be available in the future).

3.1 Future Directions for REST

REST is an evolving program with many directions for future development. Our database contains several thousand entries ranging from rare endemics to more cosmopolitan species. More species, functional traits, and restoration goals are currently being drawn from regionally-exclusive species traits lists, a comprehensive literature review, new data generated by Liko Nā Pilna and other projects, and information provided by managers familiar with REST. At present, the program and its supporting materials are available by contacting the lead authors, but plans are underway for full migration to Rebecca Ostertag's University of Hawaii faculty website (<http://hilo.hawaii.edu/uhh/faculty/ostertag/>).

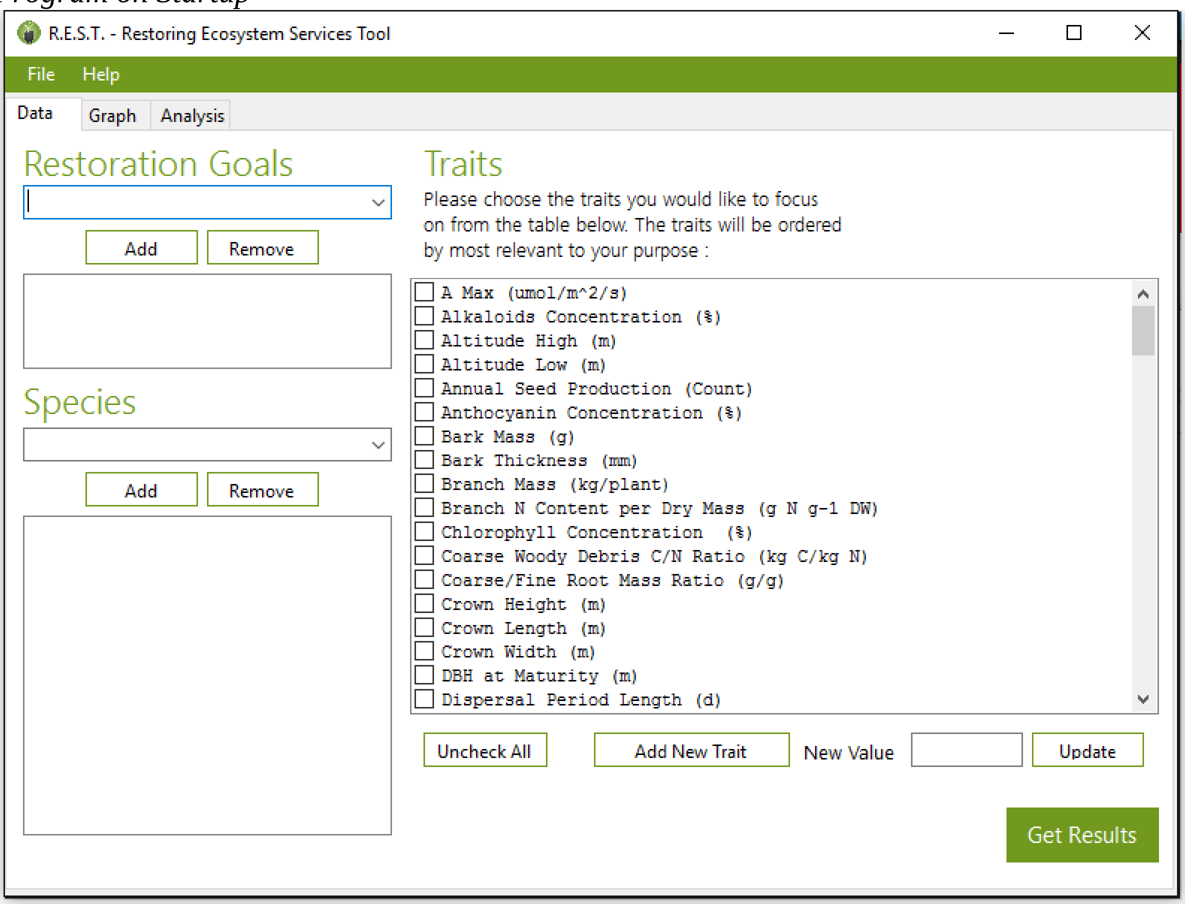
4.0 REST User Interface

When the user selects a restoration goal, a list of suggested functional traits populates in the Traits box. The user should select only the traits of interest and for which there are data. Users can tell if data are currently available by selecting a species. If trait data are available, a number will appear to the right of the trait. If there is no value, then there is no data stored within REST. Users can add data by inputting a number in the "New Value" box and clicking Update. Alternatively, users can add external .csv files with species names and associated trait data.

Installation

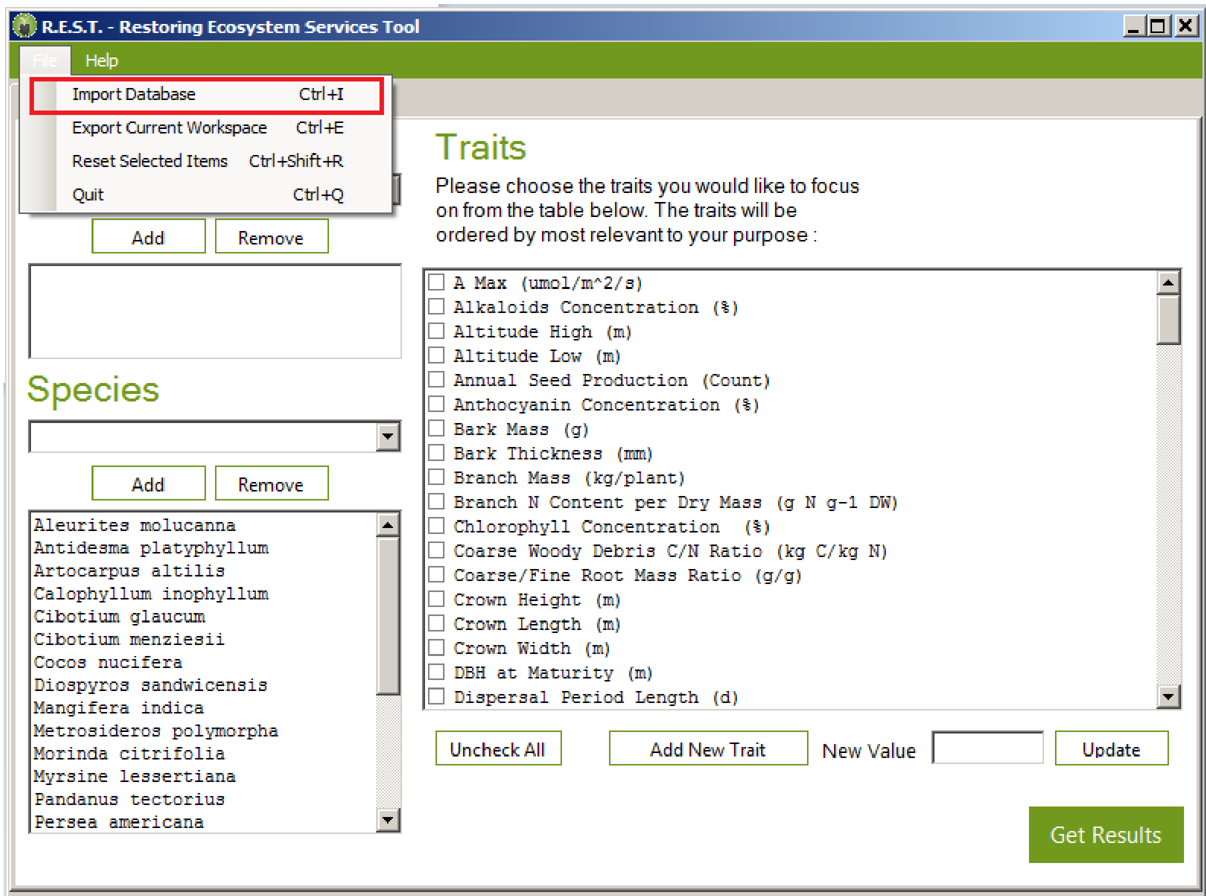
To install REST, double-click the newest version of "RESTInstaller" and follow the instructions found in the installation wizard. The program will then install itself as well as create a desktop shortcut to allow easy access.

Program on Startup



On startup, the program will appear as above. Note: each time REST is started, an internet connection is required to update the database.

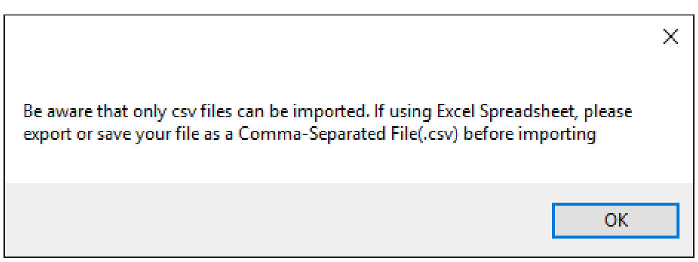
Import Database (optional)



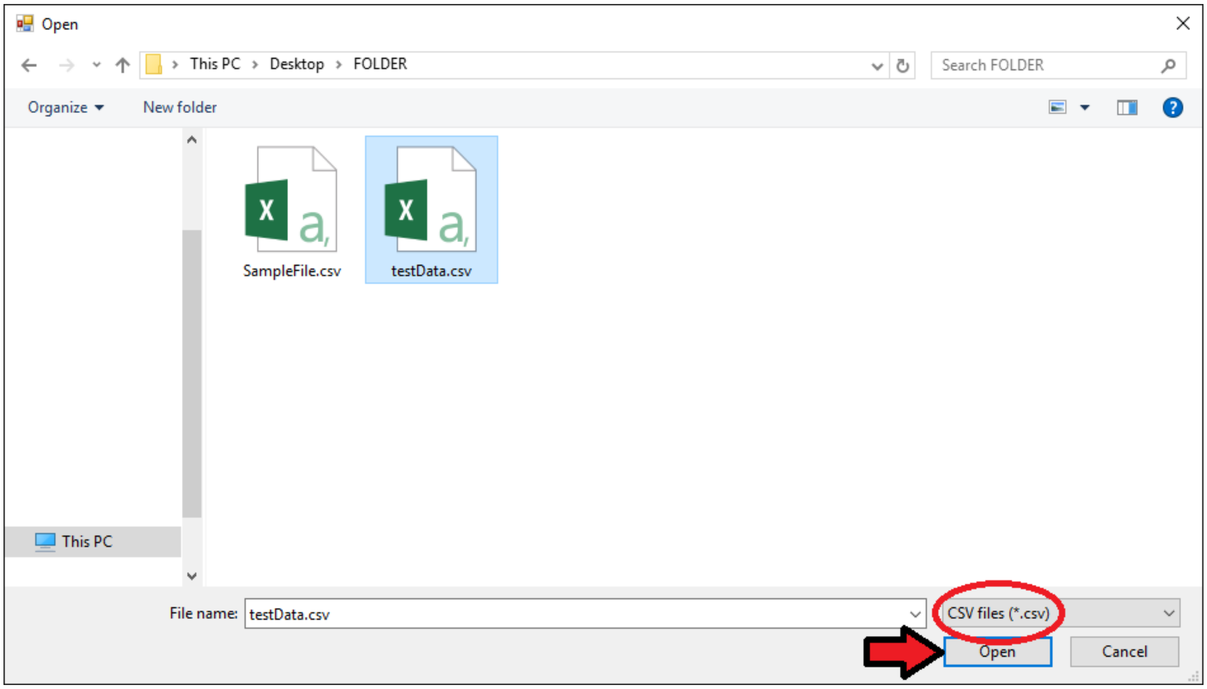
File – Import Database

Users have the option to import a personal database of species and traits in the form of a .csv file in order to skip the manual process of selecting traits and species.

Notification to use .csv files



After selecting the "import database" option, the window above will appear. This window's purpose is to warn the user that only .csv files will be accepted. Select .csv file and click "Open".



After acknowledging the previous warning, a new window will appear and you will be able to browse their personal files for any .csv files you wish to import. All .csv files can be imported, but if not formatted correctly, the program will notify you that an error has occurred and your .csv file will only be read partially.

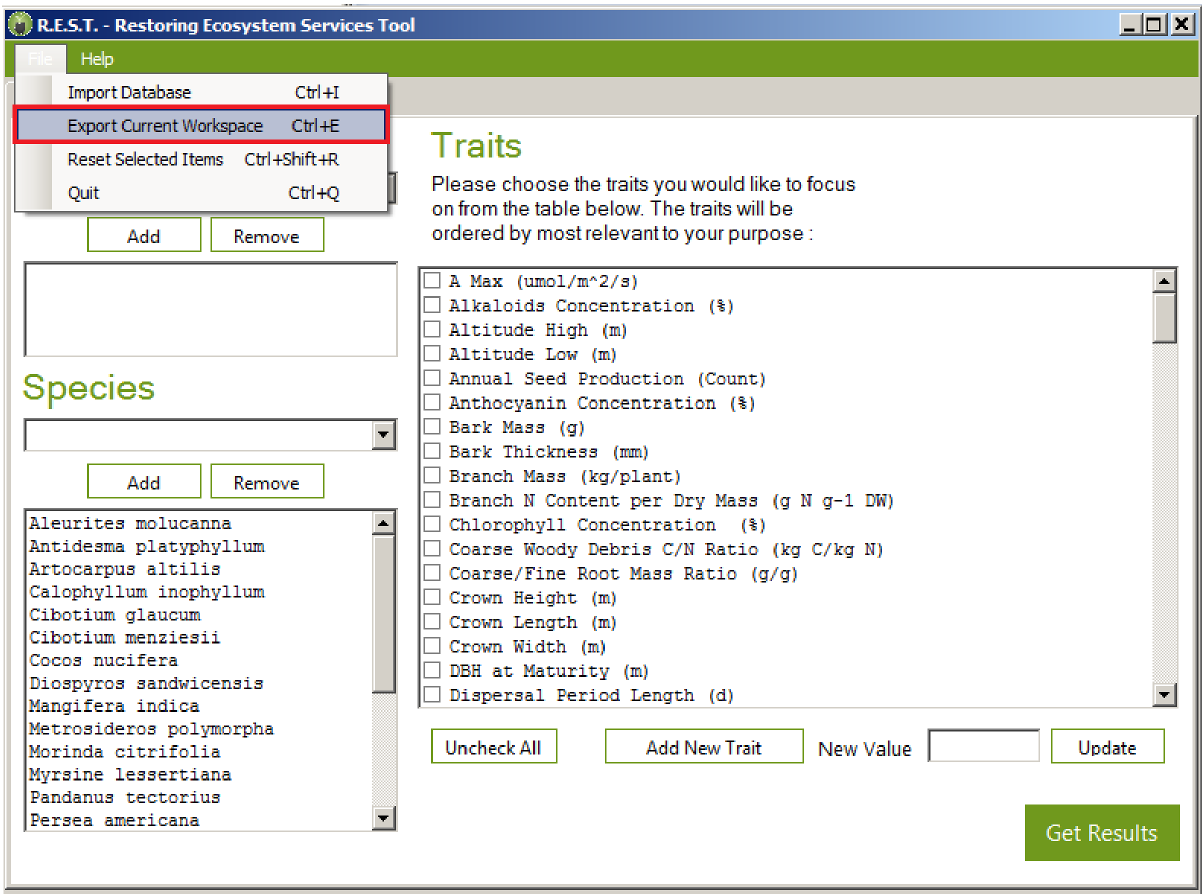
Format of .csv file

	A	B	C	D	E
1	Species	Trait1 (mm)	Trait2 (g)	Trait3 (m)	Trait4 (%)
2	species1	40	2	10	
3	species2	200	9	20	
4	species3	10	3	50	
5					
6					

The format should be species in the first column followed by traits. The units of each trait should be added to the trait name. Species and traits will appear in the program exactly as typed. (Note: if a species or trait is already in the database but spelled differently it will appear as a new trait or species.)

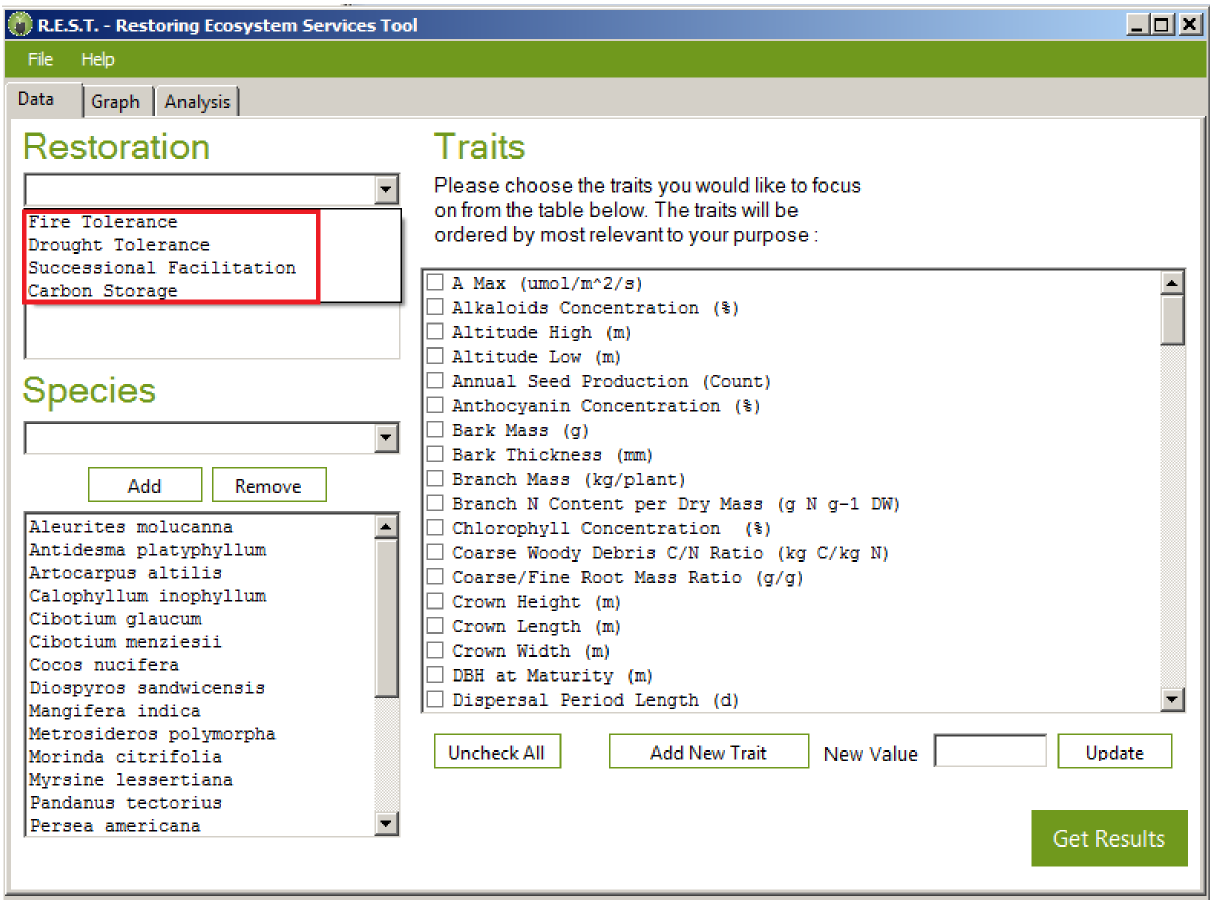
Export Workspace (optional)

File – Export Current Workspace



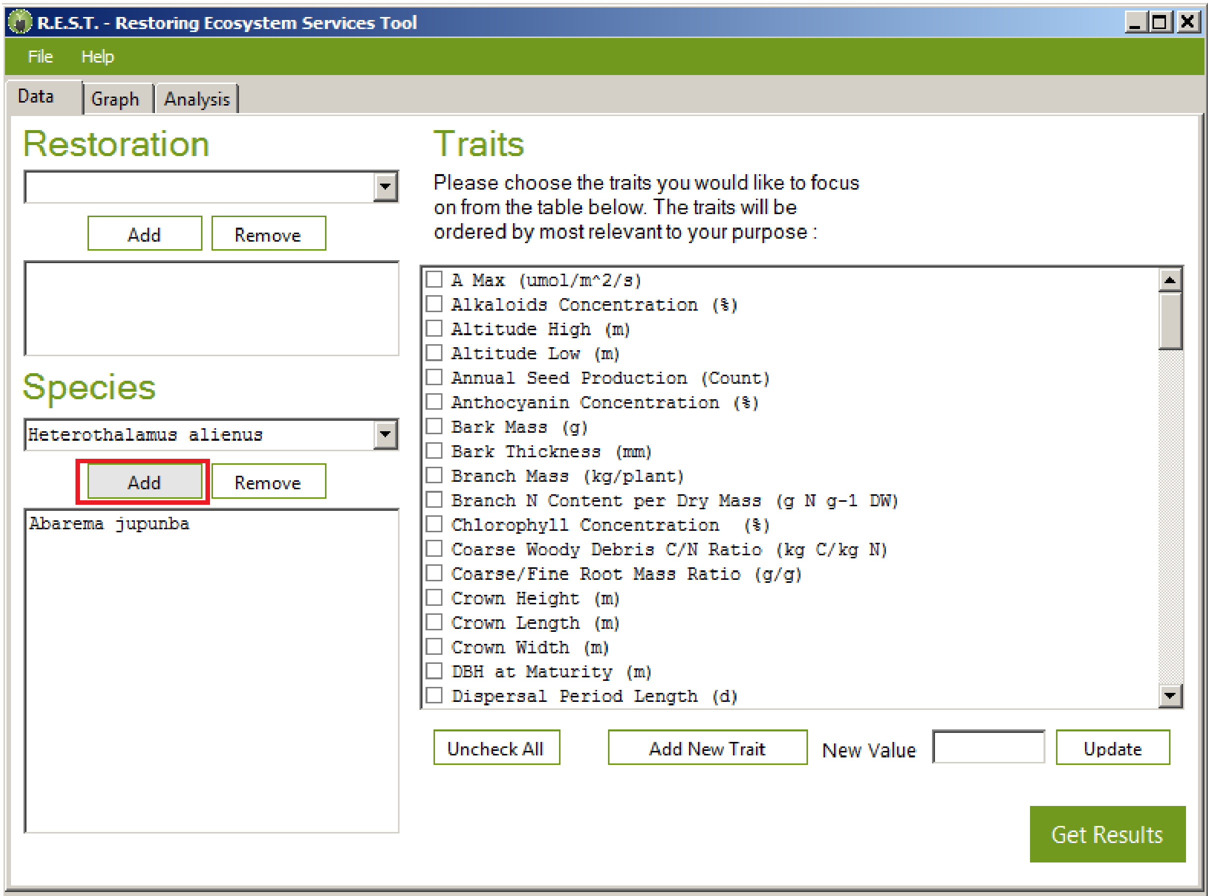
Users have the option to export a personal database of species and traits to access their results in the future. Similar to importing data, exported data takes the form of a .csv file. This same exported file can be used outside of REST as well as imported again for future use, increasing the versatility of result data.

Restoration Goals



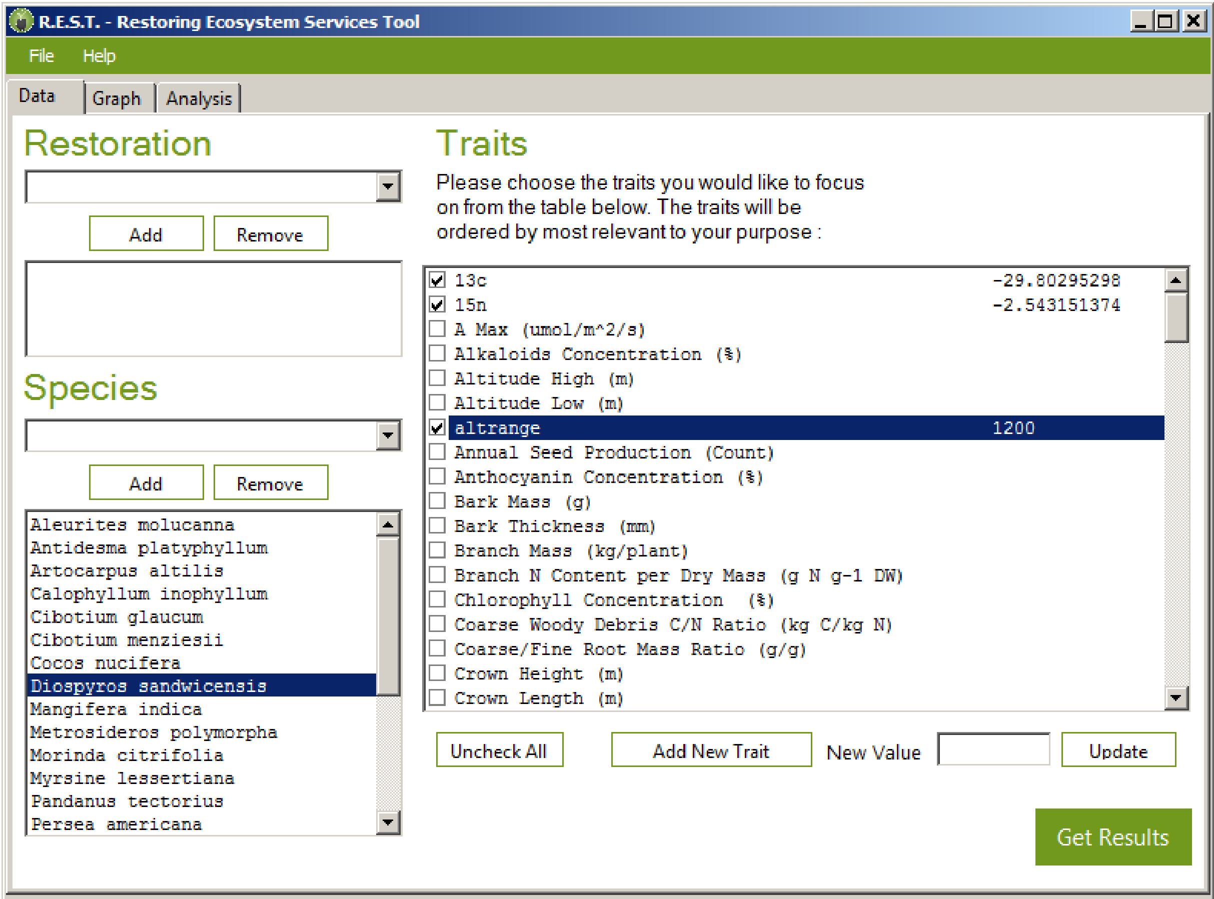
Choose a restoration goal and click "Add". This will display traits that only pertain to the chosen restoration goal(s).

Species Selection



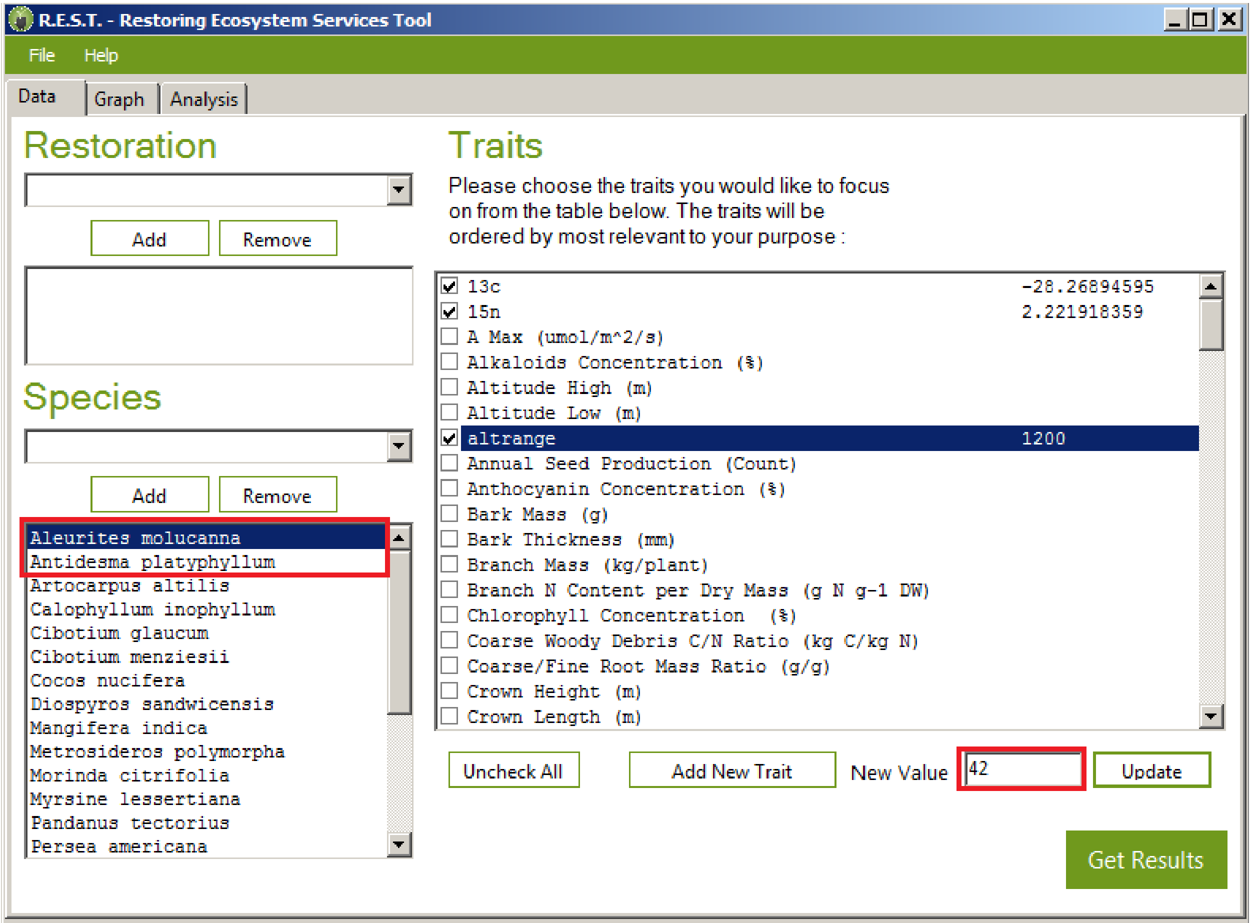
To choose a species pick a name from the menu or type the name. Click "Add" to include it in the analysis. After adding the species, the species will be added to the selected species window as shown in the following image.

Trait Selection



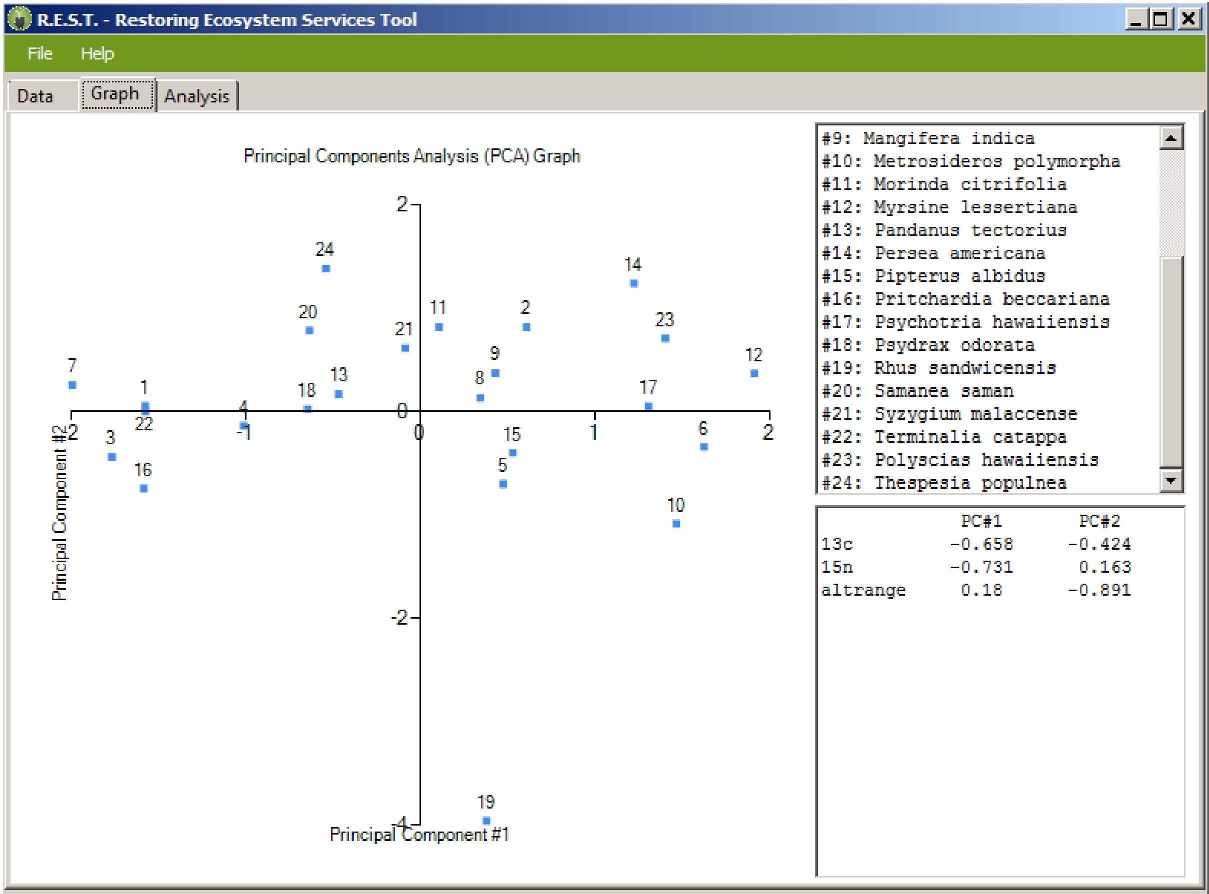
To choose a trait, click on the species and double click on the check box. If a species has data for a trait, a value will be visible to the right of the trait name. (Note: If there is no value, then there is no current data in the program for that species. REST will not complete a PCA unless all species have values for all selected traits.)

Edit Values



Click on a species to view its values. To edit a trait value click on the trait once, enter the value and click update. This will change the trait value of the *currently selected* species. (Note: the units should be consistent for that trait in the trait list.)

View Graph



When you are finished selecting your combination of traits and species, click the "Get Results" button. The graph tab will automatically open when the "Get Results" button is clicked and the results of a principal component analysis will be generated. Please note that REST will not complete a PCA if trait values are incomplete or do not align. A pop-up window will describe the changes necessary to complete the PCA.

For the PCA graph, the x-axis corresponds to values of the first principal component and the y-axis corresponds to values of the second principal component. Each of the points on the plot corresponds to a species, creating a visual representation of the relationship between two species; two species are similar if they are close to each other in the plot. To identify which point corresponds to which species, look at the number found next to the point and cross-reference that number to the legend located to the right of the graph. Numeric data associated with the PCA graph is also included, with each column corresponding to a principal component. Each principal component is a linear combination of other traits, with *n* representing the number of traits used in the analysis. The first *n* rows correspond to the coefficients of those traits in the linear combination. The last three rows displays the *eigenvalues*, the percentage of the variance captured, and associated cumulative percentage, respectively.

4.1 Restoration Goals

REST currently has four restoration goals built into the program:

1. Fire Tolerance
2. Drought Tolerance
3. Successional Facilitation
4. Carbon Storage

4.1.1 *Fire Tolerance*

Fire is a threat to many ecosystems especially with greater human development. Alternatively, fire may be a natural part of other ecosystems. Traits related to flammability are included here.

4.1.2 *Drought Tolerance*

Drought and water use by plants are important concerns. Traits relating to water storage and water use are included in the list.

4.1.3 *Successional Facilitation*

One goal of restoration may be to help a system mature to another state where there is greater animal use and later successional plant species. Traits related to growth, reproduction, and dispersal are included here. For more information, please see Pugnaire & Valladares (1999).

4.1.4 *Carbon Storage*

One restoration goal may be to maximize carbon storage across the landscape. Traits that are associated with growth and nutrient cycling are included here.

4.2 Functional Traits in REST

The following includes a list of functional traits used in REST and their units along with brief definitions, useful information for measurement, connections to restoration goals, and references for additional information where appropriate.

4.2.1 A_{max}

A_{max}, an abbreviation for maximal assimilation (presented as Amax in REST) is the maximum rate of photosynthesis. The unit for A_{max} is micromoles per square meter per second ($umol/m^2/s$ formatted as umol/m^2/s in REST). A_{max} influences carbon cycling and resource use efficiency. In REST, A_{max} is related to carbon storage and drought tolerance. For more information, please see Pugnaire & Valladares (1999).

4.2.2 *Alkaloids*

Alkaloids are chemically-basic compounds generally related to plant protection from environmental insults. Quinine, morphine, and caffeine are examples of natural alkaloids. In REST, alkaloids are measured as a percent (%) of the noted alkaloid(s). Alkaloids are related to successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.3 *Altitude*

Altitude is the range of elevations a given species occurs, with high and low respectively defining maximum and minimum limits. Altitude is measured in meters (m) and is related to drought tolerance.

4.2.4 *Annual seed production*

Annual seed production refers to seeds produced by a given species over a single year, measured as the total number of seeds. This trait is related to successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.5 *Anthocyanin concentration*

Anthocyanin concentration refers to the amount of anthocyanins, chemical plant pigments, in a given plant, expressed as percent (%). This trait is related to drought tolerance, fire tolerance, and successional facilitation.

4.2.6 *Bark mass*

Bark mass is measured in grams (g). This trait is related to carbon storage, drought tolerance, and fire tolerance.

4.2.7 *Bark thickness*

Bark thickness is measured in millimeters (mm). This trait is related to carbon storage, drought tolerance, and fire tolerance.

4.2.8 *Branch mass*

Branch mass is the total of all branches on a given plant, measured in kilograms per plant (kg/plant). This trait is connected with all restoration goals.

4.2.9 *Branch N per dry mass*

Branch N per dry mass refers to nitrogen content of dried branches, expressed as grams of nitrogen per grams of dry branch mass (formatted as g N g-1 DW in REST). This trait is connected with all restoration goals.

4.2.10 *Chlorophyll concentration*

Chlorophyll concentration is the percent (%) of a given plant that is chlorophyll. This trait is related to carbon uptake and utilization of light and all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.11 *Carbon-13 (C_{13}) content*

Carbon-13 (C_{13}) content indicates the proportion of plant tissues that consist of carbon-13 isotope, an indicator of photosynthetic pathway and integrated water-use efficiency. In REST, this trait is measured in percent (%). This trait is related to all restoration goals. For more information, please see Cornelissen et al. (2003).

4.2.12 *Coarse woody debris C/N ratio*

Coarse woody debris C/N ratio is the amount of carbon compared to the amount of nitrogen in debris of a given plant. In REST, this is expressed as kilograms of carbon divided by kilograms of nitrogen (formatted as kg C/kg N). This trait is related to all restoration goals.

4.2.13 *Crown height*

Crown height refers to the shortest distance between ground level and the upper limit of living material for a measured plant (crowns in trees). This trait is expressed in meters (m) and is connected with all restoration goals. For more information please see Cornelissen et al. (2003) and Pugnaire & Valladares (1999).

4.2.14 *Crown length*

Crown length is measured in meters (m). This trait is connected with all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.15 *Crown width*

Crown width is measured in meters (m). This trait is connected with all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.16 *DBH at maturity*

DBH at maturity refers to the diameter of a plant in meters (m) at breast height (typically 1.3 meters) when a plant is fully mature. This trait is related to carbon storage and drought tolerance. For more information, please see Pugnaire & Valladares (1999).

4.2.17 *Dispersal period length*

Dispersal period length refers to the number of days (d) a plant is dispersing seeds. This trait is connected with successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.18 *Dispersal unit length*

Dispersal unit length is measured in millimeters (mm). This trait is connected with carbon storage and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.19 *Dispersal unit thickness*

Dispersal unit thickness is measured in millimeters (mm). This trait is connected with carbon storage and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.20 *Dispersal unit width*

Dispersal unit width is measured in millimeters (mm). This trait is connected with carbon storage and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.21 *Fern spore length*

Fern spore length refers to the main units of fern reproduction. Fern spore length is expressed in micrometers (µm). This trait is connected with successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.22 *Fern spore mass*

Fern spore mass is expressed in milligrams (mg). This trait is connected with successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.23 *Fern spore volume*

Fern spore volume is expressed in micrometers (µm). This trait is connected with successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.24 *Fern spore width*

Fern spore width is expressed in micrometers (µm). This trait is connected with successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.25 *Fine root C/N ratio*

Fine root C/N ratio is the amount of carbon compared to the amount of nitrogen in the fine roots of a given plant. In REST, this is expressed as kilograms of carbon divided by kilograms of nitrogen (formatted as kg C/kg N). This trait is connected with all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.26 *Fine root dry mass per plant*

Fine root dry mass per plant is the amount of roots in kilograms (kg/plant). This trait is connected with all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.27 *Flavonoids*

Flavonoids are chemical compounds associated with nitrogen fixation, pollinator attraction, and photosynthesis. In REST, flavonoids are measured as a percent (%) of the noted the measured flavonoid(s). This trait is related to all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.28 *Flowering period length*

Flowering period length is the number of days (d) a plant produced flowers. This trait is related to successional facilitation.

4.2.29 *Freeze exposure*

Freeze exposure refers to a plant's ability to withstand freezing conditions, defined as temperatures consistently below 32° Fahrenheit (0° Celsius) prior to plant death. In REST, freeze exposure is measured in hours (h) and is associated with the goals of carbon storage and successional facilitation. Please see Fitter & Hay (2002) for more information.

4.2.30 *Fruit mass*

Fruit mass is the amount of an individual fruit of a given plant species. This is measured in grams (g) and is related to successional facilitation.

4.2.31 *Germination time*

Germination time is the number of days (d) a plant reproductive unit (such as a seed or spore) takes to sprout. Germination is related to successional facilitation. Please see Fitter & Hay (2002) for more information.

4.2.32 *Heat tolerance*

Heat tolerance refers to a plant's ability to withstand temperature conditions above its generally-accepted upper limit. In REST, heat tolerance is measured in hours (h) and is associated with all restoration goals. Please see Fitter & Hay (2002) for more information.

4.2.33 *Instantaneous water use efficiency*

One measure of water use efficiency, instantaneous, regards the ability of a plant to utilize water while capturing carbon via photosynthesis. In REST, this trait is measured in millimols of carbon gained as a proportion mols water lost (mmol/mol). This trait is related to all restoration goals. For more information, please see Way et al. (2014).

4.2.34 *Integrated water use efficiency*

Integrated water use efficiency refers to the ratio of water used in plant metabolism to water lost by productivity. This is measured by the $\delta^{13}C$ (parts per thousand; $^{0}/_{00}$) signature found in leaf tissue and is related to all restoration goals.

4.2.35 *Latex content*

Latex content regards the percent of latex production in a given plant. This trait is connected with drought tolerance, fire tolerance, and successional facilitation.

4.2.36 *Latitude*

Latitude regards the global range a plant can survive, with high and low defining respective limits for a given plant. This is measured in degrees (deg) and is related to drought tolerance.

4.2.37 *Leaf and fine root turnover*

Leaf and fine root turnover refers to the timing of shorter-lived tissue replacement in plants. Turnover is measured per year (yr^{-1}) and is related to all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.38 *Leaf area*

Leaf area is measured in square centimeters (formatted as cm^2). This trait is related to carbon storage, drought tolerance, and successional facilitation. Please see Fitter & Hay (2002) and Pugnaire & Valladares (1999) for more information.

4.2.39 *Leaf area ratio*

Leaf area ratio (LAR) refers to the photosynthetic surface area of a plant as a proportion of total dry mass. In REST, LAR is measured in square centimeters per gram (formatted as cm^2 g^-1) and is related to all restoration goals. For more information, please see Allaby (2012), Fitter & Hay (2002), and Pugnaire & Valladares (1999).

4.2.40 *Leaf C percentage*

Leaf C percentage (%) refers to the carbon content of a leaf. This trait is related to carbon storage and fire tolerance. For more information, please see Pugnaire & Valladares (1999).

4.2.41 *Leaf C:N*

Leaf C:N is the ratio of carbon to nitrogen content within a leaf. This is expressed as kilograms carbon to kilograms nitrogen (kg/kg). This trait is related to carbon storage and fire tolerance. For more information, please see Pugnaire & Valladares (1999).

4.2.42 *Leaf carbon content per area*

Leaf carbon content per area refers to the carbon content of a leaf in kilograms spread over a square meter (formatted as kg C per m^2 in REST). This trait is related to carbon storage, fire tolerance, and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.43 *Leaf chlorophyll / leaf area*

Leaf chlorophyll / leaf area refers to the chlorophyll content in grams over a square meter of leaf (formatted as g Chl m^{-2} le). This trait is related to carbon storage, drought tolerance, and successional facilitation.

4.2.44 *Leaf density*

Leaf density refers to the leaf mass in milligrams within a cubic millimeter (formatted as mg/mm3 in REST). This trait is related to carbon storage, fire tolerance, and successional facilitation. Please see Fitter & Hay (2002) and Pugnaire & Valladares (1999) for more information.

4.2.45 *Leaf dry mass*

Leaf dry mass refers to the mass of a dried leaf in grams (g). This trait is related to all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.46 *Leaf dry matter content (LDMC)*

Leaf dry matter content (LDMC) refers to the total mass of dry matter in a leaf. This is expressed as grams of dry matter over grams of total leaf matter (formatted as g/g) and is related to all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.47 *Leaf epidermis cell area*

Leaf epidermis cell area refers to the area of leaf epidermis in square micrometers (µm^2 in REST). This trait is related to carbon storage, drought tolerance, and successional facilitation.

4.2.48 *Leaf epidermis cell length*

Leaf epidermis cell length refers to the length of leaf epidermis in square micrometers (µm^2 in REST). This trait is related to carbon storage, drought tolerance, and successional facilitation.

4.2.49 *Leaf epidermis volume / leaf volume*

Leaf epidermis volume / leaf volume is the proportion of leaf volume occupied by the leaf epidermis in cubic millimeters (mm3/mm3 in REST). This trait is related to carbon storage, drought tolerance, and successional facilitation.

4.2.50 *Leaf hypodermis volume / leaf volume*

Leaf hypodermis volume / leaf volume is the proportion of leaf volume occupied by the leaf hypodermis in cubic millimeters (mm3/mm3 in REST). This trait is related to carbon storage, drought tolerance, and successional facilitation.

4.2.51 *Leaf intercellular / leaf volume*

Leaf intercellular / leaf volume is the proportion of leaf volume occupied by the leaf intercellular space in cubic centimeters (cm3/cm3 in REST). This trait is related to carbon storage, drought tolerance, and successional facilitation.

4.2.52 *Leaf intercellular CO_2 concentration*

Leaf intercellular CO_2 concentration refers to the amount of carbon dioxide in a leaf. In REST, CO_2 concentration is measured in parts per million (ppm). This trait is related to carbon storage, drought tolerance, and successional facilitation.

4.2.53 *Leaf lamina length*

Leaf lamina length is measured in centimeters (cm). This trait is related to carbon storage, drought tolerance, and successional facilitation.

4.2.54 *Leaf length*

Leaf length is measured in centimeters (cm). This trait is related to carbon storage, drought tolerance, and successional facilitation. Please see Fitter & Hay (2002) for more information.

4.2.55 *Leaf lifespan*

Leaf lifespan is measured in years (yr). This trait is related to carbon storage, drought tolerance, and successional facilitation.

4.2.56 *Leaf light absorption*

Leaf light absorption is measured in mols per mol (mol/mol). This trait is related to carbon storage, drought tolerance, and successional facilitation.

4.2.57 *Leaf mesophyll cell area*

Leaf mesophyll cell area refers to the area of leaf mesophyll in square micrometers (µm^2 in REST). This trait is related to carbon storage, drought tolerance, and successional facilitation.

4.2.58 *Leaf Mg content per dry mass*

Leaf Mg content per dry mass refers to the total amount of magnesium in grams within dry leaf matter (g g-1 DW in REST). This trait is related to carbon storage, drought tolerance, and successional facilitation.

4.2.59 *Leaf N area*

Leaf N area refers to the total amount of nitrogen contained within a given leaf area in grams per square meter (g/m2 in REST). This trait is related to all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.60 *Leaf N content / dry leaf mass*

Leaf N content / dry leaf mass refers to the nitrogen content of overall dry leaf mass in grams (g N g-1 DW in REST). This trait is related to carbon storage, fire tolerance, and successional facilitation.

4.1.61 *Leaf N percentage*

Leaf N percentage refers to the proportion of a leaf that is nitrogen (expressed at % in REST). This trait is related to carbon storage and fire tolerance. Please see Fitter & Hay (2002) for more information.

4.2.62 *Leaf N/P ratio*

Leaf N/P ratio refers to the proportion of nitrogen to phosphorus within plant leaves in grams (g/g). This trait is connected with all restoration goals.

4.2.63 *Leaf P percentage*

Leaf P percentage refers to the proportion of a leaf that is phosphorous (expressed as % in REST). This trait is related to carbon storage. Please see Fitter & Hay (2002) for more information.

4.2.64 *Leaf pH*

Leaf pH regards the acidity of a leaf, expressed as pH value in REST. This trait is related to all restoration goals. For more information, please see Fitter & Hay (2002) and Pugnaire & Valladares (1999).

4.2.65 *Leaf photosynthesis rate / leaf area*

Leaf photosynthesis rate / leaf area refers to the conversion of carbon dioxide to simple sugar over a given leaf area (expressed as umol/m^2*s in REST). This trait is related to all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.66 *Leaf thickness*

Leaf thickness is measured in millimeters (mm). This trait is related to carbon storage, drought tolerance, and fire tolerance. Please see Fitter & Hay (2002) and Pugnaire & Valladares (1999) for more information.

4.2.67 *Leaf timing*

Leaf timing refers to the number of days (d) prior to leaf emergence. This trait is related to carbon storage, drought tolerance, and successional facilitation.

4.2.68 *Leaf water content*

Leaf water content refers to the proportion of water within a leaf (expressed as % in REST). This trait is related to carbon storage, drought tolerance, and successional facilitation.

4.2.69 *Leaf weight ratio (LWR)*

Leaf weight ratio (LWR) refers to the ratio of leaf mass to plant mass expressed as grams over grams (g/g). LWR is related to all restoration goals. For more information, please see Fitter and Hay (2002).

4.2.70 *Leaf width*

Leaf width is measured in centimeters (cm). Leaf width is related to carbon storage, drought tolerance, and successional facilitation.

4.2.71 *Leaf / sapwood area ratio*

Leaf / sapwood area ratio refers to the proportion of leaves to sapwood in square millimeters (expressed as mm^2 mm^-2 in REST). This trait is related to carbon storage, drought tolerance, and fire tolerance.

4.2.72 *Litter C/N ratio*

Litter C/N ratio the amount of carbon compared to the amount of nitrogen in leaf litter of a given plant. In REST, this is expressed as kilograms of carbon divided by kilograms of nitrogen (kg C/kg N). This trait is related to all restoration goals.

4.2.73 *Litter decomposition rate*

Litter decomposition rate refers to the breakdown of dead leaves into less complex organic matter. In REST, this is expressed as percent of mass lost (mass loss %). This trait is related to carbon storage, fire tolerance, and successional facilitation. Please see Fitter & Hay (2002) and Pugnaire & Valladares (1999) for more information.

4.2.74 *Modulus of elasticity*

Modulus of elasticity refers to the 'push back' or resistance to deforming but not breaking when force is applied. The unit in REST is megapascals (MPa). This trait is related to carbon storage, drought tolerance, and fire tolerance. For more information, please see Pugnaire & Valladares (1999).

4.2.75 *N fixation*

N fixation regards the effect of nitrogen-fixing organisms in direct association with a given plant species. In REST, N fixation is expressed as percentage (%) and is related to all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.76 *Nitrogen-15 (N_{15}) content*

Nitrogen-15 (N_{15}) content indicates the proportion of plant tissues utilizing the nitrogen-15 isotope, an indicator of how plants utilize atmospheric nitrogen. In REST, this trait is measured in percent (%). This trait is related to all restoration goals. For more information, please see Kendall (2004).

4.2.77 *Petiole length*

Petiole length is measured in centimeters (cm). Petiole length is related to drought tolerance.

4.2.78 *Phenols*

Phenols refer to the percentage (%) of plant compounds containing a phenol group. These range from simple compounds synthesized in response to environmental insults to those more volatile. Capsaicin and serotonin are common examples, while certain phenols show associations with litterfall decomposition, resistance to fungal or other pests, and increased fire duration and intensity. In REST, phenols are associated with fire tolerance. For more information, please see Pugnaire & Valladares (1999).

4.2.79 *Plant annual growth rate*

Plant annual growth rate refers to how many millimeters (mm) a plant grows per year. This trait is related to all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.80 *Plant height at maturity*

Plant height at maturity refers to the height in meters (m) a plant attains when no longer considered to be in juvenile growth forms. This trait is related to drought tolerance and fire tolerance. For more information please see Cornelissen et al. (2003) and Pugnaire & Valladares (1999).

4.2.81 *Plant lifespan (average longevity)*

Plant lifespan (average longevity) refers to the time in years (yrs) a plant is expected to survive from germination to death. This can range from days for plant with relatively simple life histories to thousands of years for slow-growing species or those with clonal growth habits. This trait is related to carbon storage and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.82 *Post-fire seed emergence*

Post-fire seed emergence refers to the percentage (%) of seeds that germinate after fire events. This trait is related to carbon storage, fire tolerance, and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.83 *Post-fire seed survival*

Post-fire seed survival refers to the percentage (%) of seeds that remain viable following fire events. This trait is related to carbon storage, fire tolerance, and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.84 *QE*

Quantum efficiency, or Q_E, refers to effectiveness of capturing energy available in solar radiation. In REST, plants utilizing photosynthesis are measured in micromoles per square meter per second (umol/m^2/s). Q_E is related to carbon storage and drought tolerance.

Quantum efficiency, or Q_E, refers to effectiveness of capturing energy available in solar radiation and is expressed as a percentage; %). In REST, Q_E is related to carbon storage and drought tolerance.

4.2.85 *Re-sprouting ability clipping*

Re-sprouting ability clipping refers to the percentage (%) of damaged growth areas (leaves, branches, and related) that rejuvenate following pruning, forager browsing, or other direct removal. This trait is related to carbon storage and successional facilitation.

4.2.86 *Re-sprouting ability fire*

Re-sprouting ability fire refers to the percentage (%) of damaged growth areas (leaves, branches, and related) that rejuvenate following extreme heat, desiccation, or other conditions associated with fire. This trait is related to carbon storage, fire tolerance, and successional facilitation.

4.2.87 *Relative growth rate*

Relative growth rate (RGR) refers to increases in both mass in grams and stature in centimeters of a given plant per day (g/day cm/day in REST). RGR tends to indicate growth investment and should be considered on a whole-plant basis. This trait is related to carbon storage, drought tolerance, and fire tolerance. Please see Fitter & Hay (2002) and Pugnaire & Valladares (1999) for more information.

4.2.88 *Resin*

Resin refers to the percentage (%) of certain phenolic compounds secreted by plants in response to environmental insults. These generally refer to compounds associated with pines and aromatics such as copal, frankincense, and myrrh, but not sap, latex, or other gum-like substances. Resin is related to fire tolerance and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.89 *Root / shoot ratio*

Root / shoot ratio refers to the proportion of belowground to aboveground growth in plants (g/g). This trait is related to all restoration goals. Please see Fitter & Hay (2002) and Pugnaire & Valladares (1999) for more information.

4.2.90 *Rooting depth*

Rooting depth refers to the extent in meters (m) a given plant extends below ground level. This trait is related to all restoration goals. Please see Fitter & Hay (2002) for more information.

4.2.91 *Saponins*

Saponins refer to the percentage (%) of chemical compounds known for their ability to create foamy or frothy conditions when subjected to water. Often bitter, saponins can serve as pest deterrents due to decreased palatability. Saponins are related to fire tolerance and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.92 *Seed dispersal distance*

Seed dispersal distance refers to the distance in meters (m) seeds can occur from a mature plant. This trait is related to successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.93 *Seed length*

Seed length refers to the length in centimeters (cm) of a seed. This trait is related to carbon storage, drought tolerance, and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.94 *Seed longevity*

Seed longevity refers to the time in years (yrs) a seed remains viable. This trait is related to drought tolerance, fire tolerance, and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.95 *Seed mass*

Seed mass is measured in grams (g) and is related to successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.96 *Seed number*

Seed number refers to the expected number of seeds produced per plant. This trait is related to successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.97 *Seed number per inflorescence*

Seed number per inflorescence refers to the number of seeds produced per flowering event (expressed as 1/infloresce in REST). This trait is related to successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.98 *Seed terminal velocity*

Seed terminal velocity refers to the maximum speed a seed attains while airborne after detaching from a plant. In REST, this expressed in meters per second (m/s) and is related to successional facilitation.

4.2.99 *Seed thickness*

Seed thickness is measured in centimeters (cm). Seed thickness is related to all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.100 *Seed bank density*

Seed bank density refers to the number of seeds present per square meter of seed bank (1/m^2). This trait is related to successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.101 *Specific leaf area*

Specific leaf area is the mass in grams of a given square millimeter of leaf area (expressed as mm^2 g^-1 in REST). This trait is related to carbon storage, drought tolerance, and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.102 *Stem conduit diameter*

Stem conduit diameter refers to the size in micrometers of fluid-conducting stem portions (expressed as µm in REST). This trait is related to drought tolerance. For more information, please see Pugnaire & Valladares (1999).

4.2.103 *Stem cross-sectional area*

Stem cross-sectional area refers to the area in square micrometers of fluid-conducting stem portions (expressed as µm^2 in REST). This trait is related to drought tolerance. For more information, please see Pugnaire and Valladares (1999).

4.2.104 *Stem diameter*

Stem diameter is measured in millimeters (mm). Stem diameter is related to all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.105 *Stem length*

Stem length is measured in millimeters (mm) and is related to all restoration goals. For more information, please see Pugnaire & Valladares (1999).

4.2.106 *Stem respiration rate (stem volume)*

Stem respiration rate (stem volume) refers to the exchange of plant gases via stem tissues over a given volume (expressed as µmol m-3s-1 in REST). This trait is related to carbon storage and drought tolerance. For more information, please see Pugnaire & Valladares (1999).

4.2.107 *Stem respiration rate (surface area)*

Stem respiration rate (surface area) refers to the exchange of plant gases via stem tissues over a given area (expressed as µmol m-2s-1 in REST). This trait is related to carbon storage and drought tolerance. For more information, please see Pugnaire & Valladares (1999).

4.2.108 *Stem volume*

Stem volume is measured in cubic millimeters (mm^3 in REST). This trait is related to carbon storage, drought tolerance, and fire tolerance. For more information, please see Pugnaire & Valladares (1999).

4.2.109 *Stomata conductance per leaf area*

Stomata conductance per leaf area refers to the amount of carbon dioxide conducted per square meter of leaf are per second (mol CO2/m^2s in REST). This trait is related to carbon storage, drought tolerance, and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.110 *Stomata density*

Stomata density refers to the number of stoma per square millimeter (stom./mm2 in REST). This trait is related to carbon storage, drought tolerance, and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.111 *Tannins*

Tannins refer to the percentage (%) of protein-binding compounds produced by plants as a response to predation, fire intensity, or other environmental insults. Tannins are related to fire tolerance and successional facilitation. For more information, please see Pugnaire & Valladares (1999).

4.2.112 *Tensile strength of wood*

Tensile strength of wood is the amount of force in megapascals (MPa) that can be applied to wood prior to breaking. This trait is associated with carbon storage.

4.2.113 *Terpenes*

Terpenes refer to the percentage (%) of compounds serving a variety of protective, regulatory, and other functions in most organisms. Terpenes are often associated with resins and can be found in plants such as conifers, citrus, and carrots. In REST, terpenes are connected with fire tolerance. For more information, please see Pugnaire & Valladares (1999).

4.2.114 *Time to maturity*

Time to maturity refers to the time in months (mo) required for a germinated seed to no longer be considered juvenile. This trait is related to successional facilitation.

4.2.115 *Time to reproduction*

Time to reproduction refers to the time in months (mo) for a germinated seed to be capable of producing viable reproductive structures including flowers, seeds, and related. This trait is related to successional facilitation.

4.2.116 *Weed risk assessment score*

Hawaii Weed Risk Assessment Score refers to the likelihood of invasion or 'taking over' of a given plant species as outlined by the Hawaii Weed Risk Assessment Guide and other observational guides regarding plant-ecosystem interactions. This trait is related to drought tolerance and successional facilitation. For more information, please see Daehler (2009).

4.2.117 *Wood density / specific gravity*

Wood density / specific gravity refers to the amount of wood present within a cubic meter as measured in grams per cubic meter (g/m^3 in REST). This trait is related to carbon storage.

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