CSF.Ind - Climate Smart Forestry (CSF) Indicators Generator

1. Background

The Climate Smart Forestry (CSF) Indicators Generator (CSF.Ind) is a user-friendly Shiny web app designed to calculate CSF indicators using forest inventory data (e.g., field surveys or remote/proximal sensing forest inventory data) at tree, plot or stand levels. The app allows users to select an indicator from the two CSF pillars (i.e., Mitigation and Adaptation) and configure the analysis for one or more plots. When provided with the required data, the app generates outputs organized by forest management intensity, multi-plots, and other options. It is particularly useful for forestry technicians, stakeholders, researchers, and the public who are not familiar with climate-smart forestry assessment. CSF.Ind calculates indicators aligned with the mitigation and adaptation pillars of CSF. The generated output is specific to a given time, and when computed across multiple periods, it can be used to create composite maps of the CSF indicators.

Link GIT Framework: https://github.com/Cesarito2021/CSF.Ind.git

2. CSF output organization

The app allows users to generate outputs grouped by Forest Management Intensity (ForManInt) types or single/multi-plots (Figure 1). Grouping results by ForManInt types provides the average values across the plots included within each ForManInt type. Grouping by plots, on the other hand, displays the actual values for each individual plot. Additional grouping levels can be included upon request.
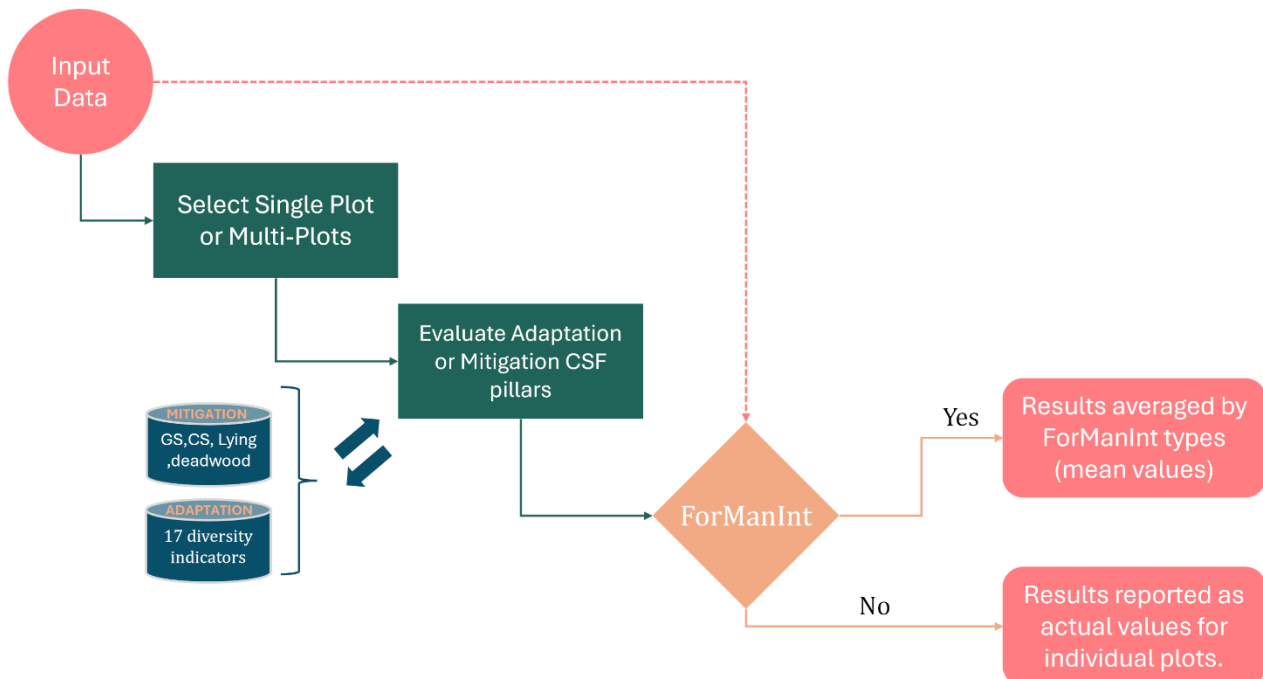

Figure 1: Scheme of the CSF indicator generation.

3. Requested data

Specific input data in an Excel file (table format) is required to generate CSF indicators using the CSF.Ind web-app. A detailed list of input data includes (Table 1):

Table 1: List of variables required for running the web app.

ID	Mandatory input data	ID	Recommendend input data	ID	Optional input data
a	ForManInt (Forest management intensity)	i	EUForestTypes (see Section 3)	l	Area of Interest (AOI) boundary (.shp)
b	IDPlot (order number),	j	CoordsPlot (Lat., Long.)	m	Single Plots boundary (.shp)
c	PlotArea (m²)	k	CoordsTree (x, y, of IDTree)		
d	TreeHeight (m)				
e	TreeDiameter (cm)				
f	TreeSpecies (see Section 3)				
g	Standing Deadwood components (2 vars)				
h	Lying Deadwood components (4 vars)				

4. Requested data explanation

Mandatory data:

a) **ForManInt** (Forest management intensity based on Dunker et al., 2012 - http://dx.doi.org/10.5751/ES-05262-170451):
- P - Passive-Unmanaged Forest nature reserve (no harvesting, 0%)
- L - Low - Close-to-nature forestry (single or group selection, <20%)
- M - Medium - Combined objective forestry (shelterwood - coppice with standards 40-70%)
- H - High - Intensive even-aged forestry (clearcut, 70-100%)
- I - Intensive - Short rotation forestry (short-rotation forestry, 100%).
- NA

b) **IDPlot** (order number): Identify number for each field plot;
c) **PlotArea** (m²): size of plot area. (A unique value is required for all plots, as it will be presented as a slider button)
d) **TreeDiameter** (cm);
e) **TreeHeight** (m);
f) **TreeSpecies** (see Section 3);
g) **Standing Deadwood Components:**
- **TreeHeightDW** (m): this is a request for stump or snag (cm)
- **TreeDiameterDW** (cm): this is a request for stump or snag (cm);
h) **Lying Deadwood Components:** When the half-diameter is supplied, "mindialog" and "maxdialog" are not required.
- **LengthLog** (m): Length of log (m)
- **MinDiaLog**: Minimum diameter of lying trees (cm; ≥10cm);
- **MaxDiaLog**: Maximum diameter of lying trees (cm; ≥10cm);
- **Half-DiaLog**: Half-diameter of log.

Recommended data:

i) **EUForestTypes**: European forest types nomenclature (see details in section 4);
j) **CoordsPlot** (Lat., Long. of IDPlot): provide the coordinates (WGS84 or ETRS89-extended / LAEA Europe) of the centroid of plot.
k) **CoordsTree**: xCoords, yCoords for IDTree (WGS84 or ETRS89-extended / LAEA Europe);

Optional:

1. **AOI_stand**: Area of Interest (AOI) boundary (.shp): shapefile of the forest stands;
2. **AOI_plots:** Single Plots boundary (.shp): shapefile of the sampling plots

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5. Further data description

Before compiling the input dataset in a table format i.e., an Excel (.xlsx) document, providers must verify specific details (Table 2; Table 3):

➢ European Forest types (Abb EUForestTypes): Please select the relevant forest type from the European forest types nomenclature. Most precisely we used the categories extracted by table 4.1., pg 28 of the European forest types categories and types for sustainable forest management reporting and policy (technical report EEA 2006 here: https://www.eea.europa.eu/publications/technical_report_2006_9). The list of EU Forest Types is provided in the Excel supplementary document.

➢ Tree species (Abb. TreeSpecies): Please use the English name of the dominant tree species or add "mixed" if no dominant tree species are present. Examples: 1) "Scots Pine", 2) "Norway Spruce", and other single tree species, and 3) the option "mixed" is represented by "Broadleaf Mixed" (mixed of broadleaf trees) or "Conifer Mixed" (mixed of conifer trees) or "BC Mixed" (mixed of broadleaf and conifer trees)(Federici et al., 2008). The list of tree species is provided in the Table 2.

Table 2: List of species that can be analyzed by the CSF.Ind app

Allometric equation from the Italian NFI source					
ID	EUTreeSpecie	ID	EUTreeSpecie	ID	EUTreeSpecie
1	European Beech	11	Maple	21	Small Conifers
2	European Larch	12	Alder	22	Eucalyptus
3	Aleppo Pine	13	Hornbeam	23	Holm Oak
4	Corsican Pine	14	Sweet Chestnut	24	Downy Oak
5	Maritime Pine	15	Ash	25	Silver Fir
6	Stone Pine	16	Black Locust	26	Turkey Oak
7	Arolla pine	17	Willow	27	other broadleaves
8	Black Pine	18	Cypress		
9	Scots Pine	19	Exotic Pines group		
10	Norway Spruce	20	Douglas Fir		

Overall, the input variables allow to assess some CSF indicators namely: ***growing stock***, ***carbon stock***, ***lying and standing deadwood***, ***age structure and/or diameter distribution*** (Table 2), obtaining several output data very helpful for additional elaboration concerning the forest structure, as well as mitigation and adaptation.

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*Table 3: Climate Smart Forestry (CSF) indicators generated by the "CSF.Ind" web-based app. Filling the "TreeSpecies" task requires a reading consideration section. All input data containing ** are slider buttom and not column data.*

Climate Smart Forestry (CSF) dataset			
Pillars	Indicator	Input Data	Output data
Mitigation	Growing Stock (single and multi-plots)	1. IDPlot (order number), 2. IDTree (order number), 3. PlotArea (m2)** 4. TreeHeight (m), 5. TreeDiameter (cm), 6. TreeSpecies. 7. ForManInt.	1. Vol_m3_ha: forest volume regarding the volume of stem and large branches (diam.>=5cm, m3/ha), 2. DomTreeSpecies: Dominant Tree Specie.
	Carbon Stock (single and multi-plots)	1. IDPlot (order number), 2. IDTree (order number), 3. PlotArea (m2)**, 4. StandVolume (corresponding to Vol_m3_ha), 5. DomTreeSpecies. 6. ForManInt.	1. AGB_tn_ha: aboveground biomass (tons/ha), 2. CS_tn_ha: Carbon Stock (tons/ha). 3.
	Lying Deadwood (single and multi-plots)	1. IDPlot (order number), 2. IDTree (order number), 3. PlotArea (m2)**, 4. LengthLog (Length of logs; m), 5. MinDiaLog (Min Ø of log ; cm), 6. MaxDiaLog (Max Ø of log; cm), 7. or (Half-Dia (cm)) 8. ForManInt.	1. LDT: Lying Deadwood Tree (m3/ha), 2. CWD: Coarse woody debris (CWD) (m3/ha), 3. SDT: Standing Deadwood Tree (m3/ha), 4. SNAG: Snag deadwood (m3/ha), All deadwood (m3/ha).
	Standing Deadwood (single and multi-plots)	1. IDPlot (order number), 2. IDTree (order number), 3. TreeHeightDW (m), 4. TreeDiameterDW (cm). 5. ForManInt.	
Adaptation	Age structure and/or diameter distribution (single and multi-plots)	1.IDPlot (order number), 2.IDTree (order number), 3.PlotArea (m2)**, 4.TreeHeight (m), 6.TreeSpecies, 7.ForManInt.	19 Diversity Indices: 1. Mean_dbh: mean of diameters at tree height (cm), 2. Mean_th = mean of tree heights (m), 3. Sum_ba: sum of basal area (m2), 4. N_sp: number of tree species, 5. SI_dbh: Simpson of diameters at tree height, 6. SH_dbh: Shannon-Weiner of diameters at tree height , 7. SD_dbh: standard deviation of diameters at tree height , 8. GI_ba: Gini of basal area, 9. CV_ba: coeficient of variation of basal area, 10. SD_th: standard deviation of tree heights, 11. CI_1000: complex index at 1000m2, 12. SHsp: Shannon-Weiner of tree species, 13. SH_th: Shannon-Weiner of tree heights, 14. SI_sp: Simpson of tree species, 15. SDI. Stand Density Index, 16. TDD: Tree Diameter Diversity, 17. THD: Tree Height Diversity, 18. VEm: Vertical Evenness Index, 19. VarDH: difference of diameter and height.

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6. Examples of input data organization

Example 1: the adequate organization of input column data in an Excel file (.xlsx) for estimating the "Growing stock" for multiple plots (similar to a single plot) is shown in the screenshot.

	A	B	C	D	E	F
1	IDPlot	IDTree	TreeSpecies	TreeDiameter	TreeHeight	ForManInt
2	3	12	Silver Fir	3	4.7	Passive
3	3	86	Silver Fir	6	6.2	Passive
4	3	92	Silver Fir	6	4.0	Passive
5	3	93	Silver Fir	3	3.9	Passive
6	7	13	Silver Fir	3	2.7	Medium
7	7	20	Silver Fir	3	2.4	Medium
8	7	21	Silver Fir	6.5	4.7	Medium
9	7	22	Silver Fir	6	5.8	Medium
L0	7	24	Silver Fir	4	3.8	Medium
L1	7	64	Silver Fir	3.5	2.9	Medium
L2	7	101	Silver Fir	5	4.4	Medium
L3	7	102	Silver Fir	4	5.2	Medium
L4	8	14	Silver Fir	5	3.7	Medium
L5	11	29	Silver Fir	7	5.9	High
L6	13	40	Silver Fir	4	4.1	High

7. Reference

Duncker, P. S., Barreiro, S. M., Hengeveld, G. M., Lind, T., Mason, W. L., Ambrozy, S., & Spiecker, H. (2012). Classification of forest management approaches: a new conceptual framework and its applicability to European forestry. Ecology and Society, 17(4).

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