STAND *BASELINE* REPORT

A3

CPF

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CLIMARK
Forest management promotion for climate change mitigation through the design of a local market of climatic credits

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STAND *BASELINE* REPORT

Action A3 of the project was differentiated into two main phases; the first involved the design of the inventory protocols for calculating the ecosystem service indicators (carbon, water and biodiversity; deliverable 4) used in this action and in the follow-up actions (D); and the second, consisted of characterising the stands and calculating the indicators based on the previously established protocols. This document presents the results of this second phase.

The main specific objectives of this second phase of action were:

- To establish a non-managed *baseline* for the different action stands, which represent different forest formations in the 6 target LU.
- The stands were characterised based on the established protocols and information was gathered in order to determine which treatments should be implemented.

The document is structured into 3 parts and 2 Appendixes. Annex 1. (Stand description sheets) includes a series of descriptive sheets for each of the implementation stands, with their forestry characteristics and *baseline* values for the selected indicators.

Contents

1. Methods used to calculate the real *baseline* for stands C1, C2 and C3-enrichment plantations

1.1. *Baseline* indicators calculated for all the LU

- C stock in woody vegetation. Based on data obtained in the field following different protocols established according to species and state of maturity, the following methods have been used (see Appendix 2 for details):

- ✓ Two methods were compared for adult stands: a) calculation based on timber volume and applying expansion factors (BEFD, defined by CREAF on the basis of the species' own allometry, which already includes density), to which the C factors of Montero et al. 2005 and the root coefficients of Ruiz-Peinado *et al.* (2011 and 2012) were applied; and b) the allometries available for the Iberian Peninsula, based on diameter, by Montero *et al*. (2005). Method a) is considered to be more precise since 2 real variables are used (diameter and height) and these are calculated from species data at county scale.
- ✓ For oak regeneration, we have used allometries developed for post-fire regeneration in Catalonia of holm oaks and oaks (Cotillas *et al.* (2006). By analogy, the same methods have been applied to the cork oak.
- ✓ For pine regeneration, given the lack of allometries suitable for this stage and the difficulty of obtaining data in the field, a specific method has been employed based on LIDAR data and the subsequent use of carbon coefficients by Montero *et al.* (2005) for Aleppo pine. By analogy, this method has been applied to the regeneration of Scots pine and black pine.
- ✓ For bushes, field estimates of cover and average height per species were obtained and the allometries of De Cáceres *et al.*, 2019, were applied, together with the carbon coefficients of Montero *et al.* (2013).

- C stock in the soil. The carbon stock has been calculated for the 4 fractions commonly used in carbon studies, in the 7 stands where the treatment is expected to have the greatest impact on soil carbon, which represent 5 of the 6 LU studied:

- ✓ Dead matter in the soil: this was calculated from samples collected in one stand from each LU, which were subsequently dried and weighed. For Action C4 of the project, work is underway to obtain a more adjusted coefficient of C incorporation into the soil; in the post-treatment calculation this fraction will include the cuttings, on the basis of crown allometries.
- ✓ Organic horizons (leaf litter). With samples collected using a 25 cm diameter metal cylinder at 15 points per stand, separation according to the degree of decomposition (L-F-H; Litter-Fermented-Humus) and laboratory analysis;
- ✓ Surficial mineral soil: Sampling with a 0-30cm probe and laboratory analysis, according to the methodology of Fuente *et al.* (1997);
- ✓ Subsurface mineral soil: Opening and characterisation of soil profile, sampling for horizons and laboratory analysis of C.

- Carbon sink capacity. Calculated from tree growth over the last 5 and 10 years.

- ✓ For adult conifers, representative tree cores were obtained, filed, and the ring width was measured. The C content was calculated according to Imaña *et al.* (2008).
- ✓ For adult oaks, cores were not taken due to the difficulty of obtaining them. Optionally, when felling, some slices may be reserved for laboratory calculation, permitting the *baseline* data to be added later.

- Risk of CO_2 emission due to fire Two dynamic indicators were used ("annual probability of fire" and "CO_2 emissions") as well as one static indicator ("vulnerability index"). For the first two indicators a specific method was developed (Alcasena *et al.*, 2019a).

- ✓ For the Annual Probability of Fire, a model of occurrence probability was developed based on an analysis of historical fires (perimeters obtained from the MITECO EGIF maps, for the period 1998-2015). Calibrated GIF simulation for each LU at 40m resolution with ARCFUESLS and Flammap, and for the whole of Catalonia at 150m resolution. Therefore, the *annual* probability was not obtained from the real figure (number of fires / number of years) but from the number of simulations carried out (> 1000). This probability is maintained as long as the same fire regime is maintained, i.e., as long as the fuel (vegetation) and the climate remain stable.
- ✓ The annual probability of fire was used to calculate the probable CO_2 emissions, and the emissions were calculated by combining the fire exposure profiles and the potential fuel consumption, calculated from the fraction consumed, which is a function of the fire intensity (length of flame).
- ✓ The vulnerability index (Piqué *et al.*, 2011) provides a direct field estimate of the vulnerability of a stand to a canopy fire, as a function of the covering of the various fuel layers and the continuity between these.

- Days with water stress (green water). Using the MEDFATE water balance simulator (from Cáceres *et al.*, 2015). Real stand structure data was used.

- Supply of water (blue water). To measure the water supplied to the water flows (surface water and underground aquifers), runoff and infiltration were estimated at stand scale, using the MEDFATE water balance simulator (de Cáceres *et al.*, 2015). Real stand structure data was used.

- Water quality. Estimated indirectly, in order to have an indicator based on the variables commonly used in forestry projects. It was assumed that water coming from forest basins was higher quality than water coming from basins with other land uses (agricultural, urban) due to the filtering role of the forest soil. It is therefore considered that the persistence of a forest body guarantees the maintenance of water quality, at a time when this is at risk from the effects of climate change (fires, drought, winds), taking into account the fact that forest management can also contribute significantly to increasing the resilience capacity of the forest mass. We propose using the Persistence Index, developed by Sanchez-Pinillos *et al*. (2016), based on the functional characteristics of the different tree and shrub species that make up the forest and which condition their capacity to respond to expected disturbances. Real stand structure data was used.

- Biodiversity. We also selected a proxy indicator based on structural forest parameters, which measures the capacity of a stand to host biodiversity (taxonomy). In this case there is an internationally recognised index, but it has been adapted to the typology of the woodlands in Catalonia: the Potential Biodiversity Index (PBI), in its version for the Mediterranean domain in Catalonia (PBIC) (IBP_Cat_MED; CPF-CNPF 2019). It is measured directly in the field transects by observing 10 factors relevant to the stand's capacity to host biodiversity (large trees, dead wood both standing and on the ground, trees with dendromicro-habitats, etc.).

Table 1. Summary table for methods used to calculate the *baseline* indicators

Indicator	Parameter	Method
1. Climate regulation		
1.1 Woody vegetation carbon stock	TOTAL WOODY VEGETATION CARBON STOCK	Adult forests: a) Calculate V*BEFD CREAF (2004) *C coef. (Montero *et al.,* 2005) and root coef. (Ruiz-Peinado *et al.,* 2011) b) Allometries Montero *et al.,* 2005 Regenerated holm oak, oak, cork oak: Allometries Cotillas. M. *et al.* (2016) Regenerated Aleppo pine, Scots pine and black pine: Method used in the project (FÖRA, 2019). Use LIDAR data, validated in the field, and apply C coef. (Montero *et al.,* 2005) and root coef. (Ruiz-Peinado *et al.,* 2011)
	Tree carbon stock (aboveground and roots)	
	Aboveground C stock	
	Root C stock	
	Matorral C stock	Allometries De Caceres *et al*. (2019) Carbon coef. Montero *et al.* (2013)
1.2 Carbon stock in the soil	TOTAL CARBON STOCK IN THE SOIL	
	C stock in the soil from dead matter	Sampling in one stand per LU, weighing and laboratory drying
	C stock in the leaf litter (Hz. Organic L-F-H)	Systematic sampling at 15 points (Fons *et al.*, 1997), with a 25 cm diameter cylinder and separation according to degree of decomposition. C analysis in the laboratory
	Surficial mineral soil C stock (0-30cm):	Systematic sampling at 15 points, with 0-30 cm probe (Fons *et al.*, 1997). C analysis in the laboratory
	Subsurface mineral soil C stock (30-120cm)	Opening and characterisation of soil profile Sampling per horizon C analysis in the laboratory.
1.3 Carbon sink capacity	C ACCUMULATED OVER THE PAST 10 YEARS	Adult conifer forests: Counting and measurement of growth rings (cores) and volume calculation from Imaña and Encinas (2008)
1.4 Risk of CO_2 emission due to fire	ANNUAL PROBABILITY OF FIRE	To model using the method developed in the project (Alcasena *et al.*, 2019). Model of occurrence probability from historical fires (EGIF maps 1998-2015-MITECO). Calibrated GIF simulation for each LU at 40m resolution.
	PROBABLE CO_2 EMISSIONS/YEAR	To model using the method developed in the project (Alcasena *et al.*, 2019). On the basis of the probability, calculation of emissions by combining fire exposure profiles and potential fuel consumption (fraction consumed as a function of fire intensity).
	VULNERABILITY INDEX	ORGEST vulnerability keys Piqué *et al.* (2011)
2. Water cycle regulation (and water supply)		
2.1 Green water	DAYS WITH WATER STRESS	Model with MEDFATE Simulator De Cáceres *et al.* (2015)
2.2 Blue water	RUNOFF + DEEP INFILTRATION – stand scale	
2.3 Water quality.	FOREST PERSISTENCE	Persistence Index (PI) Sánchez-Pinillos *et al*.2016)
3. Biodiversity		
3.1 Biodiversity	POTENTIAL BIODIVERSITY	Potential Biodiversity Index (IBPC-CAT_MED v2.1) CPF-CNPF (2019)
	Biod. Potential - Context	
	Biod. Potential - Stand	

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1.2 Additional *baseline* indicators, related to water, obtained retroactively at the end of the project

- **Water-use efficiency (WUE) at TREE scale**: by comparing the stable C and oxygen isotope ratios ($\delta^{13}C$ and $\delta^{18}O$) of the growth rings, before and after management. The fluctuations of the stable isotope ratio in the rings are used to study how the trees respond to environmental variability or changes in water competition due to management. This is based on differentiating the effects of photosynthetic activity and stoma opening in the WUE. At the end of the project, samples (cores) will be obtained and the isotope ratio of the growth rings corresponding to the 3 years before and after the action will be analysed. This will be done, at least, for the stands where there is intensive monitoring of the "water supply" service (LU Capçaleres and LU Serras d'Ancosa) and the replica in the Veneto region (Italy).

- **Infiltration and runoff at BASIN scale:** in the stands of the Catalan LUs where the "water supply" service is intensively monitored (LU Capçaleres and LU Serras d'Ancosa), two external entities are collaborating with the project to carry out real infiltration and runoff measurements at the scale of the micro-basin where the action is carried out. The methodological approaches and parameters calculated in each case vary, as indicated in the attached tables (1 and 2).

Box 1. Serres d'Ancosa LU. Cal Marimon Stand. Hydrological characterisation and experimental study - Catalan Water Agency (ACA)
Stand located in the La Laguna municipality, in the main recharge area of the **Carme-Capellades aquifer**, which supplies water to 80,000 people, as well as numerous industries and irrigation systems. Specifically, the stand is located on the eastern slope of the Plana d'Ancosa, a raised plain on fissured limestone. In spite of the high infiltration capacity of this rock type, the preliminary studies carried out by the ACA have allowed us to deduce that the micro-basin where the stand is located has a predominantly superficial and very local flow, making it a good candidate for the experimental study of how forest management impacts the water balance. The study, carried out by the ACA, consists of putting sensors in **twin basins**: an 11-hectare basin in which action has been taken on 4 hectares, and a 7-hectare control basin with no action. The sensorisation consisted of installing four piezometers (two per basin), in addition to monitoring two springs (one per basin, to obtain the ALFA) and one well. The CTFC also installed soil moisture sensors. Finally, a theoretical hydrological model has been developed, which will provide the framework for interpreting the observations from the piezometers installed. The *baseline* data will be obtained from the control basin.

Box 2. Capçaleres del Llobregat LU. Vallcebre Stand.
Hydrological characterisation and experimental study – IDAEA-CSIC

Stand located in the Vallcebre basin, on the eastern slope of the Ensija mountain range under the Cingle de Conangle. The water from the basin flows into the Saldes River, a tributary at the headwaters of the **Llobregat River**, which supplies half the population of Barcelona. The Vallcebre basin is a very closed basin within which the IDAEA-CSIC has had a hydrological station installed for 30 years. The station has generated very valuable information on the impact of vegetation cover typology on flow, erosion and the water regime, and has highlighted the role of increased tree cover in reducing the flow observed in recent decades.

The hydrological experiment designed here is based on actions on two micro-basins (<4 hectares) that have been sensorised over the last 12 years, to observe changes in the data series caused by tree extraction.

To make the comparison, the IDAEA-CSIC has analysed the daily data series collected over the period 2007-2018, which has made it possible to obtain *baseline* values (Table 1). The goal is to be able to observe how the action affects parameters such as the number of days with runoff (baseline = 5-10 days/year), and to be able to compare specific data from previous rainfall years that were similar to those monitored during the CLIMARK project. The monitoring involves the follow-up of two existing piezometers in the treated zone (one per basin), to observe changes in the data series that are attributable to the action. Six piezometers located in the untreated zone will also be monitored, as a control. The results obtained will also be compared with those from the entire Vallcebre basin.

The baseline data will be obtained from 2 sources: an analysis of the daily data series from 2007-2018 and the 6 control piezometers.

Table 1: Baseline hydrological indicators, based on the preliminary analysis of the data series

Parameter	Value (Average ± SD)	Variation during the period 2007-2018 (Min - Max)	Units
Annual surface runoff at basin scale (2.48ha) (Cal Xiscu)	19.0 ± 14.5	[0.5 / 39.8]	mm/year
Annual surface runoff coefficient (Rainfall/Runoff) at basin scale (2.48ha) (Cal Xiscu)	1.97 ± 1.39	[0.09 / 3.94]	%
Number of days per year with surface runoff at basin scale (2.48ha) (Cal Xiscu)	7.2 ± 7.1	[2 / 28]	days/year
Average annual level in piezometer 1 (Zcv08)	-2389 ± 396	[-3199 / -1976]	mm
Average annual level in piezometer 2 (Zcv10)	-1225 ± 266	[-1657 / -816]	mm

2. Visits and field work carried out for stand characterisation

To characterise the stands and calculate the indicators, it was necessary to carry out forest inventories to collect data on the selected forests, conducted by CPF technicians, with specific support from the other partners.

Different types of inventories were performed to characterise each of the stands:

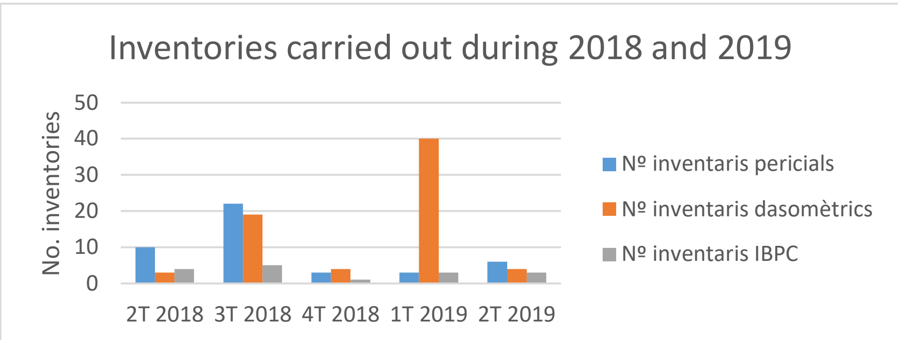
- **Preparatory inventories:** these were aimed at recording the existing variability in the stand (forestry data) in order to subsequently establish the location of the forestry measurement plot and to take into account special features when drawing up the technical specifications and executing the implementation actions. In general, three inventories were carried out per stand.
- **Tree and forest inventories:** these inventories allow precise quantification of the different tree and forest variables necessary for quantifying the action to be taken and know what changes have occurred with respect to the situation prior to the action and after it. In general, one inventory was performed per stand, except in certain stands where, due to the need for greater precision, more than one inventory was performed (stands with a water study or stands where the reaction was studied at the level of individual trees). (See Figure 1)
- **Biodiversity Inventories (PBI):** this inventory allowed us to know the biodiversity elements present in the stand and their value in both the prior and post-action situations.
- **Soil inventories:** different surficial and subsurface soil samples were taken. These inventories also involve laboratory analysis.

2.1. Forestry inventories conducted in the action stands

A total of 130 stand-characterisation forest inventories were carried out, as shown in Table 2 and Graphic 1 below:

Table 2. Forestry inventories conducted during project action A3 from Q2 2018 to Q2 2019.

	2T 2018	3T 2018	4T 2018	1T 2019	2T 2019	TOTAL
No. of expert inventories	10	22	3	3	6	**44**
No. of tree and forest inventories	3	19	4	40	4	**70**
No. of PBIC inventories	4	5	1	3	3	**16**
Total	**17**	**46**	**8**	**46**	**13**	**130**



Graph 1. Forest inventories carried out during 2018 and 2019 according to typology

Figure 1. Example of data collection in a tree and forest inventory in stand C2.1.2a at Can Budó.

2.2. Soil C inventories conducted in the demonstrative stands

Seven one-day visits were made to seven stands representative of the treatments studied with the greatest potential impact on soil in C2 stands, located in five of the six LUs studied, by CTFC researchers, with support from the University of Lleida. The field and laboratory tasks carried out to calculate the C in the four fractions commonly used in carbon studies were:

a) Dead matter in the soil: collection of samples with subsequent drying and weighing in the laboratory;
b) Organic horizons (leaf litter): samples collected using a 25 cm diameter metal cylinder at 15 points per stand, separation according to the degree of decomposition (L-F-H) and laboratory analysis;
c) Surficial mineral soil (0-30 cm): sampling with a 0-30cm probe and laboratory analysis;
d) Subsurface mineral soil (30-100 cm): opening and characterisation of the soil profile and samples collected from the horizons.

Figure 2. Field work to calculate C in the different soil fractions in C2 stands.

3. *Baseline* values obtained for the different stands

C1 Stands:

			Can Salvi (614)	Can Bech (695)	Pins Verds	El Soler Jaumàs (232)	El Soler Jaumàs (232)	Viladasses (441)	La Cortada 265	La Cortada 265
		UNITS	C1.1.1.a	C1.1.2.a	C1.2.1.a	C1.4.1.a	C1.4.2.a	C1.4.3.a	C1.4.4.a	C1.4.5.a
1.1 Woody vegetation carbon stock	TOTAL WOODY VEGETATION C STOCK(V)	tC/ha	**26,31**	**6,86**	**60,10**	**67,10**	**17,54**	**18,28**	**22,28**	**19,96**
	Tree C stock (aboveground and roots) - allometries	tC/ha	16,79	10,29	60,10	67,10	16,09	18,10	19,48	14,07
	Tree C stock (aboveground and roots) - volumes	tC/ha	26,31	6,86	60,10	67,10	17,54	18,28	22,28	19,96
	Aboveground C stock - volumes	tC/ha	17,95	4,68	46,30	50,70	13,40	13,47	17,04	14,95
	Root C stock - volumes	tC/ha	8,36	2,18	13,80	16,40	4,13	4,81	5,24	5,01
1.4 Risk of CO_2 emission due to fire	ANNUAL PROBABILITY OF FIRE	% (0-5)	**0,95**	**0,470**	**0,600**	**0,950**	**0,930**	**1,370**	**0,750**	**0,750**
	ESTIMATED CO_2 EMISSIONS/ANY	tCO_{2eq}/ha and year	**0,029**	**0,029**	**0,048**	**0,078**	**0,076**	**0,189**	**0,016**	**0,018**
	VULNERABILITY INDEX	A-B-C	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**
3. Biodiversity	POTENTIAL BIODIVERSITY - TOTAL (10)	%	**26**	**26**	**32**	**32**	**30**		**34**	**38**
	POTENTIAL BIODIVERSITY - STAND (7)	%	**11**	**17**	**26**	**17**	**14**		**37**	**34**

C3 stands – Enrichment plantations:

			Can Sabater i Puigcaní	Pla de l'Oliva
		UNITS	**C3.3.2.a**	**C3.6.1.a**
1.1 Woody vegetation carbon stock	TOTAL WOODY VEGETATION CARBON STOCK	tC/ha	**28,89**	**5,62**
	Tree C stock (aboveground and roots) - allometries	tC/ha	21,66	3,13
	Tree C stock (aboveground and roots) - volumes	tC/ha	28,89	5,62
	Aboveground C stock	tC/ha	22,86	4,14
	Root C stock	tC/ha	6,02	1,48

C2 Stands:

			Can Bech	Can Budó	Aiguaviva	Marimon pn1	Can Vich	Vallcebre-FEIXES	Vallcebre-Bosc -1	Vallcebre-Bosc - 2	Cercs	Confós	Sarda-nyés
			C2.1.1.a	C2.1.2.a	C2.2.1.a	C2.3.1.1	C2.3.2.a	C2.5.1.1a	C2.5.1.2a	C2.5.2	C2.5.3.a	C2.6.1.a	C2.6.2.a
1. Climate regulation		UNITS											
1.1 Woody vegetation carbon stock	TOTAL WOODY VEGETATION C STOCK-volumes	tC/ha	**146,38**	**105,25**	**31,64**	**97,55**	**105,36**	**114,32**	**46,84**	**72,46**	**139,92**	**188,56**	**133,85**
	Tree C stock (aboveground and roots) - allometries	tC/ha	**65,11**	**46,55**	**26,36**	**74,04**	**78,45**	**116,35**	**53,43**	**70,62**	**94,28**	**124,90**	**116,70**
	Tree C stock (aboveground and roots) **- volumes**	tC/ha	**141,42**	**104,85**	**30,64**	**96,62**	**105,34**	**114,32**	**46,70**	**72,46**	**139,92**	**188,27**	**133,45**
	Aboveground C stock - volumes	tC/ha	96,47	71,65	24,82	77,91	85,70	89,38	36,51	55,97	108,41	151,55	104,91
	Root C stock - volumes	tC/ha	44,95	33,20	5,82	18,71	19,64	24,94	10,19	16,49	31,50	36,72	28,54
	Matorral C stock aboveground)	tC/ha	4,96	0,40	1,00	0,93	0,02		0,14			0,29	0,40
1.2 Carbon stock in the soil	TOTAL CARBON STOCK IN THE SOIL	tC/ha		**49,1**	**52,1**	**121,8**			**106,6**		**118,6**	**133,1**	**131,3**
	C stock in the soil from dead matter	tC/ha		x	2,5	11,6			24,6		22,6	11,2	14,4
	C stock in the leaf litter (Hz. Organic L-F-H)	tC/ha		8,5	15,3	21,1			21,5		14,9	34,9	27,7
	Surficial mineral soil C stock (0-30cm):	tC/ha		28,5	34,2	59,0			26,6		67,1	54,1	65,0
	Subsurface mineral soil C stock (30-120cm)	tC/ha		12,0	0,0	30,2			33,9		14,0	32,9	24,3
1.3 Carbon sink capacity	C ACCUMULATED OVER THE PAST 10 YEARS	tC/ha and year			**1,11**		**0,73**		**0,5**		**0,94**	**0,68**	**1,38**
1.4 Risk of CO_2 emission due to fire	ANNUAL PROBABILITY OF FIRE	%	**0,340**	**0,200**	**0,570**	**0,740**	**1,470**	**0,020**	**0,010**	**0,080**	**0,070**	**0,060**	**1,170**
	ESTIMATED CO_2 EMISSIONS/ANY	tCO_{2eq}/ha and year	**0,025**	**0,007**	**0,045**	**0,087**	**0,169**	**0,001**	**0,000**	**0,001**	**0,007**	**0,003**	**0,035**
	VULNERABILITY INDEX	A-B-C	**A**	**A**	**A**	**C**	**B**	**C**	**C**	**C**	**C**	**A**	**A**
2. Water cycle regulation (and water supply)													
2.1 Green water	DAYS WITH WATER STRESS	days/year	**10**	**28/32**	**10//17**	**Not sig.**	**2**	**Not sig.**	**Not sig.**	**Not sig.**	**21**	**Not sig.**	**12**
2.2 Blue water	RUNOFF + deep INFILTRATION	mm/year	**534**	**432**	**64**	**170**	**136**	**199**	**357**	**291**	**77**	**172**	**276**
2.3 Water quality.	FOREST PERSISTENCE - trees	0-1	**0,44**	**0,44**	**0,67**	**0,38**	**0,67**	**0,11**	**0,11**	**0,11**	**0,26**	**0,25**	**0,11**
	FOREST PERSISTENCE - shrubs	0-1	**0,61**	**0,74**	**0,42**	**0,25**	**0,24**	**0,22**	**0,19**	**0,19**	**0,25**	**0,23**	**0,31**
3. Biodiversity													
3.1 Capacity to house biodiversity	POTENTIAL BIODIVERSITY - TOTAL (10)	%	**40**	**36**	**34**	**48**	**48**	**30**			**52**	**50**	**46**
	POTENTIAL BIODIVERSITY - STAND (7)	%	**29**	**23**	**29**	**54**	**40**	**29**			**40**	**51**	**31**

Appendix 1. Stand description factsheets